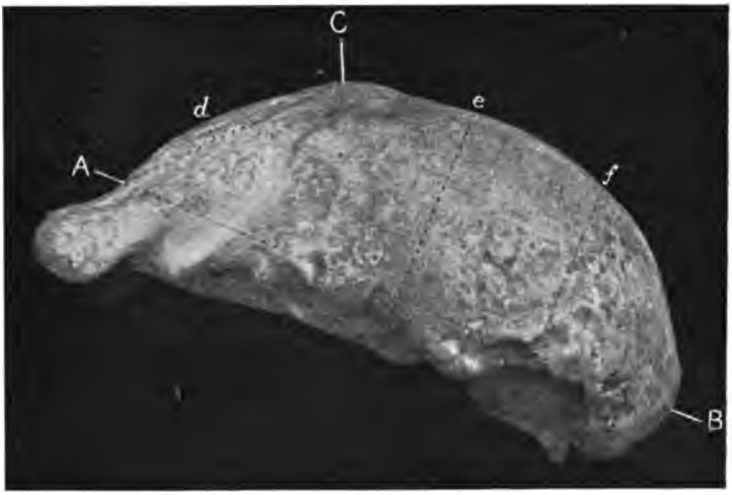
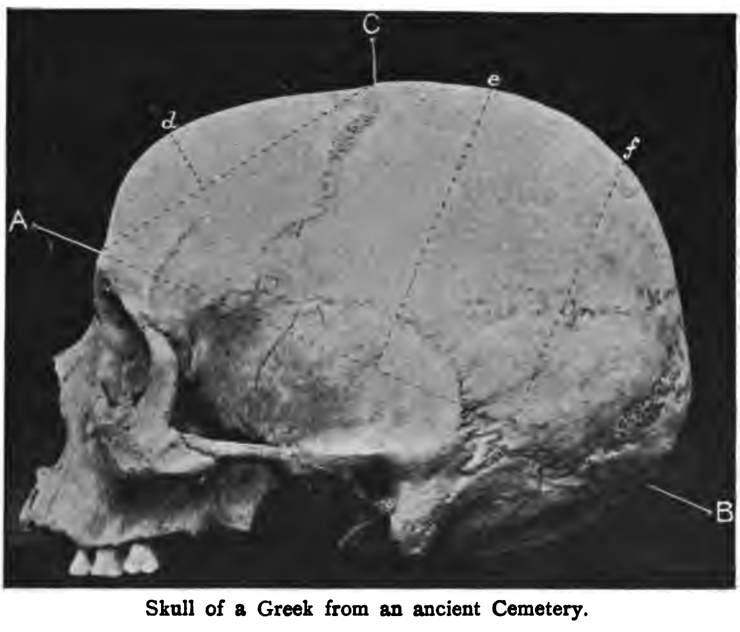
THE KINGDOM OF MAN

E. RAY LANKESTER



Cranial Dome of *Pithecanthropus erectus* from river gravel in Java.



Skull of a Greek from an ancient Cemetery.

THE KINGDOM OF MAN

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DESCRIPTION OF THE FRONTISPIECE

The upper figure is from a cast of the celebrated specimen found in a river gravel in Java, probably of as great age as the palæolithic gravels of Europe. Though rightly to be regarded as a 'man'—the creature which possessed this skull has been given the name '*Pithecanthropus*.' The shape of the cranial dome differs from that of a well-developed European human skull (shewn in the lower photograph, that of a Greek skull) in the same features as do the very ancient prehistoric skulls from the Belgian caves of Spey, and from the Neanderthal of the Rhineland. These differences are, however, measurably greater in the Javanese skull.

The three great features of difference are: (1) the great size of the eye-brow ridges (the part below and in front of A in the figures) in the Java skull; (2) the much greater relative height of the middle and back part of the cranial dome (lines *e* and *f*) in the Greek skull; (3) the much greater prominence in the Greek skull of the front part of the cranial dome —the prefrontal area or frontal 'boss' (the part in front of the line A C, the depth of which is shewn by the line *d*).

The parts of the cranial cavity thus obviously more capacious in the Greek skull are precisely those which are small in the Apes and overlie those convolutions of the brain which have been specially developed in Man as compared with the highest Apes.

The line A B in both the figures is the ophryo-tentorial line. It is drawn from the ophryon (the mid-point in the line drawn across the narrowest part of the frontal bone just above the eye-brow ridges), which corresponds externally to the most anterior limit of the brain, to the extra-tentorial point (between the occipital ridges) and is practically the base line of the cerebrum. The lines *e* and *f* are perpendiculars on this base line, the first half-way between A and B, the second half-way between the first and the extra-tentorial point.

C is the point known to craniologists as 'bregma,' the meeting point of the frontal and the two parietal bones.

The line A C is drawn as a straight line joining A and C—but if the skull is accurately posed it corresponds to the edge of the plane at right angles to the sagittal plane of the skull—which traverses both bregma (C) and ophryon (A)—and where it 'cuts' the skull marks off the prefrontal area or boss. (See for the full-face view of this area in the two skulls—Figs. 1 and 2.) The line *d* is a perpendicular let fall from the point of greatest prominence of the prefrontal area on to the prefrontal plane. It indicates the depth of the prefrontal cerebral region. Drawn on both sides on the surface of the bone and looked at from in front (the white dotted line in Figs. 1 and 2) it gives the maximum breadth of the prefrontal area.

By dividing the ophryo-tentorial line into 100 units, and using those units as measures, the depths of the brain cavity in the regions plumbed by the lines *d*, *e*, and *f*, can be expressed numerically and their differences in a series of skulls stated in percentage of the ophryo-tentorial length.

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LIST OF ILLUSTRATIONS

PREFACE

This little volume is founded on three discourses which I have slightly modified for the present purpose, and have endeavoured to render interesting by the introduction of illustrative process blocks, which are described sufficiently fully to form a large extension of the original text.

The first, entitled 'Nature's Insurgent Son,' formed, under another title, the Romanes lecture at Oxford in 1905. *Its object is to exhibit in brief the 'Kingdom of Man,' to shew that there is undue neglect in the taking over of that possession by mankind, and to urge upon our Universities the duty of acting the leading part in removing that neglect.*

The second is an account, which served as the presidential address to the British Association at York in 1906, *of the progress made in the last quarter of a century towards the assumption of his kingship by slowly-moving Man.*

The third, reprinted from the Quarterly Review, *is a more detailed account of recent attempts to deal with a terrible disease—the Sleeping Sickness of tropical Africa—and furnishes an example of one of the innumerable directions in which Man brings down disaster on his head by resisting the old rule of selection of the fit and destruction of the unfit, and is painfully forced to the conclusion that knowledge of Nature must be sought and control of her processes eventually obtained. I am glad to be able to state that as a result of the representations of the Tropical Diseases Committee of the Royal Society, and, as I am told, in some measure in consequence of the explanation of the state of things given in this essay, funds have been provided by the Colonial Office for the support of a professorship of*

Protozoology in the University of London, to which Mr. E. A. Minchin has been appointed. It is recognized that the only way in which we can hope to deal effectually with such diseases as the Sleeping Sickness is by a greatly increased knowledge of the nature and life-history of the parasitic Protozoa which produce those diseases.

I have to thank Mr. John Murray for permission to reprint the article on Sleeping Sickness, and I am also greatly indebted to scientific colleagues for assistance in the survey of progress given in the second discourse. Amongst these I desire especially to mention Mr. Frederick Soddy, F.R.S., Prof. H. H. Turner, F.R.S., Prof. Sydney Vines, F.R.S., Mr. MacDougal of Oxford, and Prof. Sherrington, F.R.S. To Mr. Perceval Lowell I owe my thanks for permission to copy two of his drawings of Mars, and to the Royal Astronomical Society for the loan of the star-picture on p. 90.

E. RAY LANKESTER,
January, 1907.

THE KINGDOM OF MAN

CHAPTER I

NATURE'S INSURGENT SON

1. THE OUTLOOK.

IT has become more and more a matter of conviction to me—and I believe that I share that conviction with a large body of fellow students both in this country and other civilized states—that the time has arrived when the true relation of Nature to Man has been so clearly ascertained that it should be more generally known than is at present the case, and that this knowledge should form far more largely than it does at this moment, the object of human activity and endeavour, —that it should be, in fact, the guide of state-government, the trusted basis of the development of human communities. That it is not so already, that men should still allow their energies to run in other directions, appears to some of us a thing so monstrous, so injurious to the prosperity of our fellow men, that we must do what lies within our power to draw attention to the conditions and circumstances which attend this neglect, the evils arising from it, and the benefits which must follow from its abatement.

2. THE WORD 'NATURE.'

The signification attached to the word 'Nature' is by no means the same at the present day as it has been in the past: as commonly used it is a word of

varied meanings and limitations, so that misconception and confusion is liable to be associated with it. By the professed student of modern sciences it is usually understood as a name for the entire mechanism of the universe, the kosmos in all its parts; and it is in this sense that I use it. But many still identify 'Nature' with a limited portion of that great system, and even retain for it a special application to the animals and plants of this earth and their immediate surroundings. Thus we have the term 'natural history' and the French term 'les sciences naturelles' limited to the study of the more immediate and concrete forms of animals, plants, and crystals. There is some justification for separating the conception of Nature as specially concerned in the production and maintenance of living things from that larger Nature which embraces, together with this small but deeply significant area, the whole expanse of the heavens in the one direction and Man himself in the other. Giordano Bruno, who a little more than 300 years ago visited Oxford and expounded his views, was perhaps the first to perceive and teach the unity of this greater Nature, anticipating thus in his prophetic vision the conclusion which we now accept as the result of an accumulated mass of evidence. Shakespeare came into touch with Bruno's conception, and has contrasted the more limited and a larger (though not the largest) view of Nature in the words of Perdita and Polyxenes. Says Perdita:—

> ' . . . the fairest flowers o' the season
> Are our carnations, and streak'd gillyvors,
> Which some call Nature's bastards; of that kind
> Our rustic garden's barren; and I care not
> To get slips of them. . . . For I have heard it said,
> There is an art which, in their piedness, shares
> With great creating nature.'

To which Polyxenes replies:—

'Say there be—
Yet nature is made better by no mean,
But nature makes that mean: so, over that art,
Which, you say, adds to nature, is an art
That nature makes. You see, sweet maid, we marry
A gentle scion to the wildest stock;
And make conceive a bark of baser kind
By bud of nobler race; this is an art
Which does mend nature,—change it, rather: but
The art itself is nature.'

The larger proportion of so-called educated people even at the present day have not got beyond Perdita's view of Nature. They regard the territory of Nature as a limited one, the play-ground or sport of all sorts of non-natural demons and fairies, spirits and occult agencies. Apart from any definite scheme or conception of these operations, they personify Nature and attribute a variety of virtues and tendencies to her for which there is no justification. We are told, according to the fancy of the speaker, that such a course is in accordance with Nature; that another course is contrary to Nature; we are urged to return to Nature and we are also urged to resist Nature. We hear that Nature will find a remedy for every ill, that Nature is just, that Nature is cruel, that Nature is sweet and our loving mother. On the one hand Man is regarded as outside of and opposed to Nature, and his dealings are contrasted favourably or unfavourably with those of Nature. On the other hand we are informed that Man must after all submit to Nature and that it is useless to oppose her. These contradictory views are in fact fragments of various systems of philosophy of various ages in which the word 'Nature' has been assigned equally various limitations and extensions. Without attempting to discuss the history and justification of

these different uses of the word Nature, I think that I may here use the word Nature as indicating the entire kosmos of which this cooling globe with all upon it is a portion.

3. Nature-searchers.

The discovery of regular processes, of expected effects following upon specified antecedents, of constant properties and qualities in the material around him, has from the earliest recorded times been a chief occupation of Man and has led to the attainment by Man of an extraordinarily complex control of the conditions in which his life is carried on. But it was not until Bruno's conception of the unity of terrestrial nature with that of the kosmos had commended itself that a deliberate and determined investigation of natural processes, with a view to their more complete apprehension, was instituted. One of the earliest and most active steps in this direction was the foundation, less than 250 years ago, of the Royal Society of London for the Promotion of Natural Knowledge, by a body of students who had organized their conferences and inquiries whilst resident in Oxford.[1]

[1] The foundation of the Royal Society of London is most intimately connected with the University of Oxford. Dr. Wallis, an original member, writes :—'I take its first ground and foundation to have been in London about the year 1645, when Dr. Wilkins and others met weekly at a certain day and hour. . . . About the year 1648–9 some of our company were removed to Oxford; first Dr. Wilkins, then I, and soon after Dr. Goddard. Those in London continued to meet there as before (and we with them, when we had occasion to be there), and those of us at Oxford; with Dr. Ward (since Bishop of Salisbury), Dr. Ralph Bathurst (now President of Trinity College in Oxford), Dr. Petty (since Sir William Petty), Dr. Willis (then an eminent physician in Oxford), and divers others, continued such meetings in Oxford

All over Western Europe such associations or academies for the building up of the New Philosophy (as it was called here) came into existence. It is a fact which is strangely overlooked at the present day, when the assumption is made that the acquirement of a knowledge of Greek grammar is the traditional and immemorial occupation of Oxford students—that until the modern days of the eighteenth century ('modern' in the history of Oxford) Greek was less known in Oxford than Hebrew is at present, and that the study of Nature —Nature-knowledge and Nature-control—was the appropriate occupation of her learned men. It is indeed a fact that the very peculiar classical education at present insisted on in Oxford, and imposed by her on the public schools of the country, is a modern innovation, an unintentional and, in a biological sense, 'morbid' outgrowth of that 'Humanism' to which a familiarity with the dead languages was, but is no longer, the pathway.

4. The Doctrine of Evolution.

What is sometimes called the scientific movement, but may be more appropriately described as the Nature-searching movement, rapidly attained an immense

and brought those studies into fashion there; meetings first at Dr. Petty's lodgings (in an apothecarie's house) because of the convenience of inspecting drugs and the like, as there was occasion; and after his remove to Ireland (though not so constantly) at the lodgings of Dr. Wilkins, then Warden of Wadham College, and after his removal to Trinity College in Cambridge, at the lodgings of the Honourable Mr. Robert Boyle, then resident for divers years in Oxford. . . . In the meanwhile our company at Gresham College being much again increased by the accession of divers eminent and noble persons, upon his Majesty's return, we were (about the beginning of the year 1662) by his Majesty's grace and favour incorporated by the name of the Royal Society.'

development. In the latter half of the last century this culminated in so complete a knowledge of the movements of the heavenly bodies, their chemical nature and physical condition—so detailed a determination of the history of the crust of this earth and of the living things upon it, of the chemical and physical processes which go on in Man and other living things, and of the structure of Man as compared with the animals most like him, and of the enormous length of time during which Man has existed on the earth—that it became possible to establish a general doctrine of the evolution of the kosmos, with more special detail in regard to the history of this earth and the development of Man from a lower animal ancestry. Animals were, in their turn, shown to have developed from simplest living matter, and this from less highly elaborated compounds of chemical 'elements' differentiated at a still earlier stage of evolution. There is, it may be said without exaggeration, no school or body of thinkers at the present day who are acquainted with the facts now ascertained, which denies the orderly evolution of the kosmos by the regular operation of a more or less completely ascertained series of properties resident in the material of which it consists.[1] The process of evolution—the interaction of these ascertainable, if not fully ascertained properties—has led (it is held), in the case of the cooling cinder which we call the earth—by an inevitable and predestined course—to the formation of that which we call living matter and eventually of Man himself. From this process all disorderly or arbitrary interferences must, it seems, be excluded. The old fancies as to presiding demons or fairies—which it was imagined had for

[1] See, however, the letter from the *Times*, reprinted on p. 62.

their business to interrupt the supposed feeble and limited efforts of Nature, as yet unexplored and unappreciated—have passed out of mind. The consensus is complete: Man is held to be a part of Nature, a product of the definite and orderly evolution which is universal; a being resulting from and driven by the one great nexus of mechanism which we call Nature. He stands alone, face to face with that relentless mechanism. It is his destiny to understand and to control it.

5. Unwarranted inferences from the Evolution of Man.

There are not wanting those who, accepting this conclusion, seek to belittle Man and endeavour to represent that the veil is lifted, that all is 'explained' obvious, commonplace, and mean in regard to the significance of life and of Man, because it has become clear that the kosmic process has brought them forth in due order. There are others who rightly perceive that life is no common property of our cooling matter, but unique and exceptional, and that Man stands apart from and above all natural products, whether animate or inanimate. Some of these thinkers appear to accept the conclusion that if life and Man are regarded as products of the kosmic process—that is, of Nature —'life' and 'Man' lose so much in importance and significance that dire consequences must follow to Man's conception of his dignity and to the essential features of his systems of conduct and social organization. Accordingly they cling to the belief that living matter and Man have not proceeded from an orderly evolution of Nature, but are 'super' natural. It is

found on the other hand, by many who have considered these speculations, and hold no less explicitly than do the 'supernaturalists' that life is a momentous and peculiar feature of our earth's surface and Man the isolated and unparalleled 'piece of work,' 'the beauty of the world,' 'the paragon of animals'—it is found by many such, I say, that nothing is gained in regard to our conception of Man's nobility and significance by supposing that he and the living matter which has given rise to him, are not the outcome of that system of orderly process which we call Nature.

There is one consideration in regard to this matter which, it seems, is often overlooked and should be emphasized. It is sometimes—and perhaps with a sufficient excuse in a want of acquaintance with Nature—held by those who oppose the conclusion that Man has been evolved by natural processes, that the products of Nature are arbitrary, haphazard, and due to chance, and that Man cannot be conceived of as originating by chance. This notion of 'chance' is a misleading figment inherited by the modern world from days of blank ignorance. The 'Nature-searchers' of to-day admit no such possibility as 'chance.' It will be in the recollection of many here, that a leading writer and investigator of the Victorian Era, the physicist John Tyndall, pointed out in a celebrated address delivered at Belfast that according to the conceptions of the mechanism of Nature arrived at by modern science—the structure of that mechanism is such that it would have been possible for a being of adequate intelligence inspecting the gaseous nebula from which our planetary system has evolved to have foreseen in that luminous vapour the Belfast audience and the professor addressing it!

The fallacy that in given but unknown circumstances anything whatever may occur in spite of the fact that some one thing has been irrevocably arranged to occur, is a common one.[1] It is correct to assume in the absence of any pertinent knowledge (if we are compelled to estimate the probabilities) that one event is as likely as another to occur; but nevertheless there is no 'chance' in the matter since the event has been already determined, and might be predicted by those possessing the knowledge which we lack. Thus then it appears that the conclusion that Man is a part of Nature is by no means equivalent to asserting that he has originated by 'blind chance'; it is in fact a specific assertion that he is the predestined outcome of an orderly—and to a large extent 'perceptible'—mechanism.[2]

[1] There is a tendency among writers on Variation, as affording the opportunity for the operation of Natural Selection, to assume that the variations presented by organisms are minute variations in every direction around a central point. Those observers who have done useful work in showing the definite and limited character of organic variations have very generally assumed that they are opposing a commonly held opinion that variation is of this equally distributed character. I cannot find that Mr. Darwin made any such assumption; and it is certain, and must on reflection have been recognized by all naturalists, that the variations by the selection and intensification of which natural selection has produced distinct forms or species, and in the course of time altogether new groups of plants and animals, are strictly limited to definite lines rendered possible, and alone possible, by the constitution of the living matter of the parental organism. We have no reason to suppose that the offspring of a beetle could in the course of any number of generations present variations on which selection could operate so as to eventually produce a mammalian vertebrate; or that, in fact, the general result of the process of selection of favourable variations in the past has not been *ab initio* limited by the definite and restricted possibilities characteristic of the living substance of the parental organisms of each divergent line or branch of the pedigree.

[2] See p. 62.

6. Nature's Mode of Producing Organic Forms.

The general process by which the higher and more elaborate forms of life, and eventually man himself, have been produced has been shown by Darwin to depend upon two important properties of living matter manifested in connexion with the multiplication of individuals. Living matter has a special property of adding to its bulk by taking up the chemical elements which it requires and building up the food so taken as additional living matter. It further has the power of separating from itself minute particles or germs which feed and grow independently, and thus multiply their kind. It is a fundamental character of this process of reproduction that the detached or pullulated germ inherits or carries with it from its parents the peculiarities of form and structure of its parent. This is the property known as Heredity. It is most essentially modified by another property—namely, that though eventually growing to be closely like the parent, the germ (especially when it is formed, as is usual, by the fusion of two germs from two separate parents) is never identical in all respects with the parent. It shows Variation. In virtue of Heredity, the new congenital variations shown by a new generation are transmitted to their offspring when in due time they pullulate or produce germs. Man has long been aware of this; and, by selecting variations of beasts, birds, or plants agreeable or useful to him, has intensified such variations and produced animals and plants in many features very unlike those with which he started.

It was Darwin's merit to show that a process of selection which he called 'Natural Selection' must take place

in the free untouched conditions under which animals and plants exist, and have existed for ages, on this globe. Both animals and plants produce germs, or young, in excess—usually in vast excess. The world, the earth's surface, is practically full, that is to say, fully occupied. Only one pair of young can grow up to take the place of the pair—male and female—which have launched a dozen, or it may be as many as a hundred thousand, young individuals on the world. The property of Variation ensures that amongst this excess of young there are many differences. Eventually those survive which are most fitted to the special conditions under which this particular organism has to live. The conditions may, and indeed in long lapses of time must, change, and thus some variation not previously favoured will gain the day and survive. The 'struggle for existence' of Darwin is the struggle amongst all the superabundant young of a given species, in a given area, to gain the necessary food, to escape voracious enemies, and gain protection from excesses of heat, cold, moisture, and dryness. One pair in the new generation—only one pair—survive for every parental pair. Animal population does not increase: 'Increase and multiply' has never been said by Nature to her lower creatures. Locally, and from time to time, owing to exceptional changes, a species may multiply here and decrease there; but it is important to realize that the 'struggle for existence' in Nature—that is to say, among the animals and plants of this earth untouched by man—is a desperate one, however tranquil and peaceful the battlefield may appear to us. The struggle for existence takes place, not as a clever French writer[1] glibly informs

[1] M. Paul Bourget of the Académie Française, is not only a charming writer of modern 'novels,' but claims to be a 'psychologist,' a title

his readers, between different species, but between individuals of the same species, brothers and sisters and cousins. The struggle between a beast of prey which seeks to nourish itself and the buffalo which defends its life with its horns is not 'the struggle for existence' so named by Darwin. Moreover, the struggle among the members of a species in natural conditions differs totally from the mere struggle for advancement or wealth

which perhaps may be conceded to every author who writes of human character. His works are so deservedly esteemed, and his erudition is as a rule, so unassailable, that in selecting him as an example of the frequent misrepresentation, among literary men, of Darwin's doctrine, I trust that my choice may be regarded as a testimony of my admiration for his art. In his novel *Un Divorce*, published in 1904, M. Bourget, says : 'La lutte entre les espèces, cette inflexible loi de l'univers animal, a sa correspondance exacte dans le monde des idées. Certaines mentalités constituent de véritables espèces intellectuelles qui ne peuvent pas durer à côté les unes des autres' (Edition Plon, p. 317). This inflexible law of the animal universe, the struggle between species, is one which is quite unknown to zoologists. The 'struggle for existence,' to which Darwin assigned importance, is not a struggle between different species, but one between closely similar *members of the same species.* The struggle between species is by no means universal, but in fact very rare. The preying of one species on another is a moderated affair of balance and adjustment which may be described rather as an accommodation than as a struggle.

A more objectionable misinterpretation of the naturalists' doctrine of the survival of the fittest in the struggle for existence is that made by journalists and literary politicians, who declare, according to their political bias, either that science rightly teaches that the gross quality measured by wealth and strength alone can survive and should therefore alone be cultivated, or that science (and especially Darwinism) has done serious injury to the progress of mankind by authorizing this teaching. Both are wrong, and owe their error to self-satisfied flippancy and traditional ignorance in regard to nature-knowledge and the teaching of Darwin. The 'fittest' does not mean the 'strongest.' The causes of survival under Natural Selection are very far indeed from being rightly described as mere strength, nor are they baldly similar to the power of accumulating wealth. Frequently in Nature the more obscure and feeble survive in the struggle because of their modesty and suitability to given conditions, whilst the rich are sent empty away and the mighty perish by hunger.

with which uneducated writers so frequently compare it. It differs essentially in this—that in Nature's struggle for existence, death, immediate obliteration, is the fate of the vanquished, whilst the only reward to the victors—few, very few, but rare and beautiful in the fitness which has carried them to victory—is the permission to reproduce their kind—to carry on by heredity to another generation the specific qualities by which they triumphed.

It is not generally realized how severe is the pressure and competition in Nature—not between different species, but between the immature population of one and the same species, precisely because they are of the same species and have exactly the same needs. From a human point of view the pressure under which many wild things live is awful in its severity and relentless tenacity. Not only are new forms established by natural selection, but the old forms, when they exactly fit the mould presented as it were for competitive filling, are maintained by the same unremitting process. A distinctive quality in the beauty of natural productions (in which man delights) is due to the unobtrusive yet tremendous slaughter of the unfit which is incessantly going on, and the absolute restriction of the privilege of parentage to the happy few who attain to the standard described as 'the fittest.'

7. The Limited Variety of Nature's Products.

The process of development of an immense variety of animal and vegetable forms has proceeded in this way through countless ages of geologic time, but it must not be supposed that any and every conceivable form and variety has been produced. There are only

two great diverging lines of descent from original living matter—only the animals and the plants. And in each of these there are and have been only a limited number of branches to the pedigree—some coming off at a lower level, others at higher points when more elaborate structure has been attained. It is easy to imagine groups of both plants and animals with characters and structures which have never existed and never will exist. The limitation of the whole process in spite of its enormous duration in time, its gigantic output and variety, is a striking and important fact. Linnaeus said, 'There are just as many species as in the beginning the Infinite Being created'; and the modern naturalist can go no further than the paraphrase of this, and must say, 'There are and have been just so many and just so few varieties of animal and vegetable structure on this earth as it was possible for the physical and chemical contents of the still molten globe to form up to the hour now reached.'

8. The Emergence of Man.

As to how and when man emerged from the terrestrial animal population so strictly controlled and moulded by natural selection is a matter upon which we gain further information year by year. There must be many here who remember, as I do, the astounding and almost sudden discovery some forty-five years ago of abundant and overwhelming evidence that man had existed in Western Europe as a contemporary of the mammoth and rhinoceros, the hyaena and the lion. The dispute over the facts submitted to the scientific world by Boucher de Perthes was violent and of short duration. The immense antiquity of man was established and accepted on all sides just before Mr. Darwin published

his book on *The Origin of Species*. The palæolithic implements, though not improbably made 150,000 years ago, do not, any more than do the imperfect skulls occasionally found in association with them, indicate a condition of the human race much more monkey-like than is presented by existing savage races (see Figs. 1 and 2 and Frontispiece, and their explanations). The implements themselves are manufactured with great skill and artistic feeling. Within the last ten years much rougher flint implements, of peculiar types, have been discovered in gravels which are 500 feet above the level of the existing rivers (see Figs. 3 and 4). These Eoliths of the South of England indicate a race of men of less-developed skill than the makers of the Palæoliths, and carry the antiquity of man at least as far back beyond the Palæoliths as these are from the present day. We have as yet found no remains giving the direct basis for conclusions on the subject; but judging by the analogy (not by any means a conclusive method) furnished by the history of other large animals now living alongside of man—such as the horse, the rhinoceros, the tapir, the wolf, the hyaena, and the bear—it is not improbable that it was in the remote period known as the lower Miocene—remote even as compared with the gravels in which Eoliths occur—that Natural Selection began to favour that increase in the size of the brain of a large and not very powerful semi-erect ape which eventuated, after some hundreds of thousands of years, in the breeding-out of a being with a relatively enormous brain-case, a skilful hand, and an inveterate tendency to throw stones, flourish sticks, protect himself in caves, and in general to defeat aggression and satisfy his natural appetites by the use of his wits rather than by strength alone—in which,

FIG. 1.—*Pithecanthropus* from Java

FIG. 2.—Greek Skull

FIGS. 1 AND 2.

Photographs of a front view of the two skulls shewn in profile in the frontispiece, taken so as to shew the breadth of the 'forehead' or prefrontal area, which is seen to be very much greater in the Greek skull (Fig. 2) than in the Javanese *Pithecanthropus* (Fig. 1). The prefrontal area is marked out by a black dotted line, the outline of a plane (the prefrontal plane) which is at right angles to the sagittal plane and passes through the meeting point of the frontal with the two parietal bones above; whilst below it passes through the median point called 'ophryon.' The plane of the picture is parallel with this prefrontal plane. The white dotted line gives the breadth of the boss-like prefrontal area. It is identical in position with the line *d* in the side view of the same skulls given in the frontispiece. The black dotted line is identical in position with the line A C in those figures. The two specimens are equally reduced in the photograph. (Original).

FIG. 3.

FIG. 3.

Photographs of eight Eoliths of one and the same shape, namely, with a chipped or worked tooth-like prominence, rendering the flint fit for use as a 'borer'—photographed of half the actual size (linear measurement) from specimens found near Ightham, Kent, in the high-level gravel—which form part of the Prestwich collection in the Natural History Museum, Cromwell Road, London. Many others of the same shape have been found in the same locality. These and the trinacrial implements photographed in Fig. 4 are far older than the oval and leaf-shaped 'palæoliths' of the low-lying gravels of the valleys of the Thames, Somme, and other rivers. (Original).

Fig. 4.

FIG. 4

Photographs of six Eoliths of the 'shoulder-of-mutton' or 'trinacrial type—from the same locality and collection as those shewn in Fig. 3. The photographs are of half the length of the actual specimens. A considerable number of worked flints of this peculiar shape have been found in the same locality. Possibly their shape enabled the primitive men who 'chipped' and used them to attach them by thongs to a stick or club. The descriptive term 'trinacrial' is suggested by me for these flints in allusion to the form of the island of Sicily which they resemble. (Original)

however, he was not deficient. Probably this creature had nearly the full size of brain and every other physical character of modern man, although he had not as yet stumbled upon the art of making fire by friction, nor converted his conventional grunts and groans, his screams, laughter, and interjections into a language corresponding to (and thenceforth developing) his power of thought.

9. The Enlarged Brain.

The leading feature in the development and separation of man from amongst other animals is undoubtedly the relatively enormous size of the brain in man, and the corresponding increase in its activities and capacity. It is a very striking fact that it was not in the ancestors of man alone that this increase in the size of the brain took place at this same period, viz. the Miocene. The great mammals such as the titanotherium, which represented the rhinoceros in early Tertiary times, had a brain which was in proportion to the bulk of the body, not more than one-eighth the volume of the brain of the modern rhinoceros (see Fig. 5). Other great mammals of the earlier Tertiary period were in the same case; and the ancestors of the horse, which are better known than those of any other modern animal, certainly had very much smaller brains in proportion to the size of their bodies than has their descendant.

We may well ask to what this sudden and marked increase in the size of the brain in several lines of the animal pedigree is due. It seems that the inborn hereditary nervous mechanism by which many simple and necessary movements of the body are controlled and brought into relation with the outer world acting upon the sense-organs, can be carried in a relatively

small bulk of brain-substance. Fish, lizards, and crocodiles with their small brains carry on a complex and effective life of relation with their surroundings. It appears that the increased bulk of cerebral substance means increased 'educability'—an increased power of storing up individual experience—which tends to take the place of the inherited mechanism with which it is often in antagonism. The power of profiting by individual experience, in fact educability, must in conditions of close competition be, when other conditions are equal, an immense advantage to its possessor. It seems that we have to imagine that the adaptation of mammalian form to the various conditions of life had in Miocene

A B C D

FIG. 5.

Four casts of the brain-cavities of a series of large Ungulate Mammals in order to shew the relatively small size of the cerebral hemispheres of the extinct creature from which A is taken.

A is that of *Dinoceras*, a huge extinct Eocene mammal which was as large as a Rhinoceros; B is that of Hippopotamus; C of Horse; and D of Rhinoceros.

times reached a point when further alteration and elaboration of the various types, which we know then existed, could lead to no advantage. The variations presented for selection in the struggle for existence presented no advantage—the 'fittest' had practically been reached, and was destined to survive with little

change. Assuming such a relative lull in the development of mere mechanical form, it is obvious that the opportunity for those individuals with the most 'educable' brains to defeat their competitors would arise. No marked improvement in the instrument being possible, the reward, the triumph, the survival would fall to those who possessed most skill in the use of the instrument. And in successive generations the bigger and more educable brains would survive and mate, and thus bigger and bigger brains be produced.

It would not be difficult (though not, perhaps, profitable) to imagine the conditions which have favoured the continuation of this process to a far greater length in the Simian line of the pedigree than in other mammalian groups. The result is that the creature called Man emerged with an educable brain of some five or six times the bulk (in proportion to his size and weight) of that of any other surviving Simian. Great as is this difference, it is one of the most curious facts in the history of man's development that the bulk of his brain does not appear to have continued to increase in any very marked degree since early Palaeolithic times. The cranial capacity of many savage races and of some of the most ancient human skulls is only a little less than that of the average man of highly-civilised race. The value of the mental activities in which primitive man differs from the highest apes may be measured in some degree by the difference in the size of the man's and the ape's brain; but the difference in the size of the brain of Isaac Newton and an Australian black-fellow is not in the remotest degree proportionate to the difference in their mental qualities. Man, it would seem, at a very remote period attained the extraordinary development of brain which marked him off from the rest of the

animal world, but has ever since been developing the powers and qualities of this organ without increasing its size, or materially altering in other bodily features.[1]

10. The Progress of Man.

The origin of Man by the process of Natural Selection is one chapter in man's history; another one begins with the consideration of his further development and his diffusion over the surface of the globe.

The mental qualities which have developed in Man, though traceable in a vague and rudimentary condition in some of his animal associates, are of such an unprecedented power and so far dominate everything else in his activities as a living organism, that they have to a very large extent, if not entirely, cut him off from the general operation of that process of Natural Selection and survival of the fittest which up to their appearance had been the law of the living world. They justify the view that Man forms a new departure in the gradual unfolding of Nature's predestined scheme. Knowledge, reason, self-consciousness, will, are the attributes of Man. It is not my purpose to attempt to trace their development from lower phases of mental activity in man's animal ancestors, nor even to suggest the steps by which that

[1] A short discussion of this subject and the introduction of the term 'educability' was published in a paper by me entitled 'The Significance of the Increased Size of the Cerebrum in recent as compared with extinct Mammalia,' Cinquantenaire de la Société de Biologie, Paris, 1899, pp. 48–51.

It has been pointed out to me by my friend Dr. Andrews, of the Geological Department of the British Museum, that the brain cavity of the elephants was already of relatively large size in the Eocene members of that group, which may be connected with the persistence of these animals through subsequent geological periods.

development has proceeded. What we call the will or volition of Man—a discussion of the nature and limitation of which would be impossible in these pages and is happily not necessary for my present purpose—has become a power in Nature, an *imperium in imperio*, which has profoundly modified not only man's own history but that of the whole living world and the face of the planet on which he exists. Nature's inexorable discipline of death to those who do not rise to her standard—survival and parentage for those alone who do—has been from the earliest times more and more definitely resisted by the will of Man. If we may for the purpose of analysis, as it were, extract Man from the rest of Nature of which he is truly a product and part, then we may say that Man is Nature's rebel. Where Nature says 'Die!' Man says 'I will live.' According to the law previously in universal operation, Man should have been limited in geographical area, killed by extremes of cold or of heat, subject to starvation if one kind of diet were unobtainable, and should have been unable to increase and multiply, just as are his animal relatives, without losing his specific structure and acquiring new physical characters according to the requirements of the new conditions into which he strayed—should have perished except on the condition of becoming a new morphological 'species.' But Man's wits and his will have enabled him to cross rivers and oceans by rafts and boats, to clothe himself against cold, to shelter himself from heat and rain, to prepare an endless variety of food by fire, and to 'increase and multiply' as no other animal without change of form, without submitting to the terrible axe of selection wielded by ruthless Nature over all other living things on this globe. And as he has more and more obtained this control over his surroundings, he has

expanded that unconscious protective attitude towards his immature offspring which natural selection had already favoured and established in the animal race, into a conscious and larger love for his tribe, his race, his nationality, and his kind. He has developed speech, the power of communicating, and above all of recording and handing on from generation to generation his thought and knowledge. He has formed communities, built cities, and set up empires. At every step of his progress Man has receded further and further from the ancient rule exercised by Nature. He has advanced so far and become so unfitted to the earlier rule, that to suppose that Man can 'return to Nature' is as unreasonable as to suppose that an adult animal can return to its mother's womb.

In early tribal times natural selection still imposed the death penalty on failure. The stronger, the more cunning, the better armed, the more courageous tribe or family group, exterminated by actual slaughter or starvation the neighbouring tribes less gifted in one or all of these qualities. But from what we know of the history of warlike exterminating savage tribes at the present day —as, for instance, the Masai of East Africa—it seems unlikely that the method of extermination—that is, of true natural selection—had much effect in man's development after the very earliest period. Union and absorption were more usual results of the contact of primitive tribes than struggles to the death. The expulsion of one group by another from a desired territory was more usual than the destruction of the conquered. In spite of the frequent assertions to the contrary, it seems that neither the more ancient wars of mankind for conquest and migration nor the present and future wars for commercial privilege have any real equivalence to the simple removal

by death of the unfit and the survival and reproduction of the fit, which we know as Natural Selection.[1]

The standard raised by the rebel man is not that of 'fitness' to the conditions proffered by extra-human nature, but is one of an ideal comfort, prosperity, and conscious joy in life—imposed by the will of man and involving a control and in important respects a subversion of what were Nature's methods of dealing with life before she had produced her insurgent son. The progress of man in the acquirement of this control of Nature has been one of enormous rapidity within the historical period, and within the last two centuries has led on the one hand to immensely increased facilities in the application of mechanical power, in locomotion, in agriculture, and in endless arts and industries; and on the other hand to the mitigation of disease and pain. The men whom we may designate as 'the Nature-searchers'—those who founded the New Philosophy of the Invisible College at Oxford and the Royal Society in London—have placed boundless power in the hands of mankind.

II. The Attainment by Man of the Knowledge of his Relations to Nature.

But to many the greatest result achieved by the progress of Natural Knowledge seems not to have been so

[1] It would be an error to maintain that the process of Natural Selection is entirely in abeyance in regard to Man. In an interesting book, *The Present Evolution of Man*, Dr. Archdall Reid has shown that in regard to zymotic diseases, and also in regard to the use of dangerous drugs such as alcohol and opium, there is first of all the acquirement of immunity by powerful races of men through the survival among them of those strains tolerant of the disease or of the drug, and secondly, the introduction of those diseases and drugs by the powerful immune race,

much in its practical applications and its material gifts to humanity as in the fact that Man has arrived through it at spiritual emancipation and freedom of thought.

In the latter part of the last century man's place in Nature became clearly marked out by the accumulation of definite evidence. The significance and the immeasurable importance of the knowledge of Nature to philosophy and the highest regions of speculative thought are expressed in the lines of one who most truly and with keenest insight embodied in his imperishable verse the wisdom and the aspirations of the Victorian age:—

'Flower in the crannied wall,
I pluck you out of the crannies:
I hold you here, root and all, in my hand
Little flower—but if I could understand
What you are, root and all, and all in all,
I should know what God and man is.'

To many the nearer approach to that 'understanding' has seemed the greatest and a sufficient result of scientific researches. The recognition that such an understanding leads to such vast knowledge would seem to ensure further and combined effort to bring it nearer and nearer to the complete form, even if the perfect understanding of the 'all in all' be for ever unattainable. Nevertheless, the clearer apprehension, so recently attained, of man's origin and destiny, and of the enormous powers of which he has actually the control, has not led to any very obvious change in the attitude of responsible leaders of human activity in the great civilized communities of the world. They still attach little or no importance to the acquirement of a knowledge of Nature: they remain fixed in the

in its migrations, to races not previously exposed either to the diseases or the drugs, and a consequent destruction of the invaded race. The survival of the fittest is, in these cases, a survival of the tolerant and eventually of the immune.

old ruts of traditional ignorance, and obstinately turn their faces towards the past, still believing that the teachings and sayings of antiquity and the contemplation, not to say the detailed enumeration, of the blunders and crimes of its ancestors, can furnish mankind with the knowledge necessary for its future progress. The comparative failure of what may be called the speculative triumph of the New Philosophy to produce immediate practical consequences has even led some among those prejudiced by custom and education in favour of the exclusive employment of Man's thought and ingenuity in the delineation and imaginative resurrection of the youthful follies and excesses of his race, to declare that the knowledge of Nature is a failure, the New Philosophy of the Nature-searchers a fraud. Thus the well-known French publicist M. Brunetière has taken upon himself to declare what he calls the Bankruptcy of Science.

12. The Regnum Hominis.

As a matter of fact the new knowledge of Nature—the newly-ascertained capacity of Man for a control of Nature so thorough as to be almost unlimited—has not as yet had an opportunity for showing what it can do. A lull after victory, a lethargic contentment, has to some extent followed on the crowning triumphs of the great Nature-searchers whose days were numbered with the closing years of that nineteenth century which through them marks an epoch. No power has called on Man to arise and enter upon the possession of his kingdom—the 'Regnum Hominis' foreseen by Francis Bacon and pictured by him to an admiring but incredulous age with all the fervour and picturesque detail of which he was capable. And yet at this moment the mechanical diffi-

culties, the want of assurance and of exact knowledge, which necessarily prevented Bacon's schemes from taking practical shape, have been removed. The will to possess and administer this vast territory alone is wanting.

13. Man's Destiny.

Within the last few years an attempt to spur the will of Englishmen in this direction has been made by some who have represented that this way lie great fortunes, national ascendancy, imperial domination. The effort has not met with much success. On the other hand, I speak for those who would urge the conscious and deliberate assumption of his kingdom by Man—not as a matter of markets and of increased opportunity for the cosmopolitan dealers in finance—but as an absolute duty, the fulfilment of Man's destiny,[1] a necessity the incidence of which can only be deferred and not avoided.

This, is indeed, the definite purpose of my discourse; to point out that civilized man has proceeded so far in his interference with extra-human nature, has produced for himself and the living organisms associated with him such a special state of things by his rebellion against natural selection and his defiance of Nature's pre-human dispositions, that he must either go on and acquire firmer control of the conditions or perish miserably by the vengeance certain to fall on the half-hearted meddler in great affairs. We may indeed compare civilized man to a successful rebel against Nature who by every step forward renders himself liable to greater and greater penalties, and so cannot afford to pause or fail in one single

[1] 'Religion means the knowledge of our destiny and of the means of fulfilling it.'—*Life and Letters of Mandell Creighton sometime Bishop of London*, vol. ii. p. 195.

step. Or again we may think of him as the heir to a vast and magnificent kingdom who has been finally educated so as to fit him to take possession of his property, and is at length left alone to do his best; he has wilfully abrogated, in many important respects, the laws of his mother Nature by which the kingdom was hitherto governed; he has gained some power and advantage by so doing, but is threatened on every hand by dangers and disasters hitherto restrained: no retreat is possible—his only hope is to control, as he knows that he can, the sources of these dangers and disasters. They already make him wince: how long will he sit listening to the fairy-tales of his boyhood and shrink from manhood's task?

A brief consideration of well-ascertained facts is sufficient to show that Man, whilst emancipating himself from the destructive methods of natural selection, has accumulated a new series of dangers and difficulties with which he must incessantly contend.

14. Man and Disease.

In the extra-human system of Nature there is no disease and there is no conjunction of incompatible forms of life, such as Man has brought about on the surface of the globe. In extra-human Nature the selection of the fittest necessarily eliminates those diseased or liable to disease. Disease both of parasitic and congenital origin occurs as a minor phenomenon. The congenitally diseased are destroyed before they can reproduce: the attacks of parasites great and small either serve only to carry off the congenitally weak, and thus strengthen the race, or become harmless by the survival of those individuals which, owing to peculiar qualities in their tissues, can tolerate such attacks with-

out injury, resulting in the establishment of immune races. It is a remarkable thing—which possibly may be less generally true than our present knowledge seems to suggest—that the adjustment of organisms to their surroundings is so severely complete in Nature apart from Man, that diseases are unknown as constant and normal phenomena under those conditions. It is no doubt difficult to investigate this matter, since the presence of Man as an observer itself implies human intervention. But it seems to be a legitimate view that every disease to which animals (and probably plants also) are liable, excepting as a transient and very exceptional occurrence, is due to Man's interference. The diseases of cattle, sheep, pigs, and horses, are not known except in domesticated herds and those wild creatures to which Man's domesticated productions have communicated them. The trypanosome lives in the blood of wild game and of rats without producing mischief. The hosts have become tolerant of the parasite. It is only when man brings his unselected, humanly-nurtured races of cattle and horses into contact with the parasite, that it is found to have deadly properties.[1] The various cattle-diseases which in Africa have done so much harm to native cattle, and have in

[1] This has been established in the case of the *Trypanosoma Brucei* a minute parasite living in the blood of big game in south-east Africa, amongst which it is disseminated by a blood-sucking fly, the *Glossina morsitans* or Tsetze fly. The parasite appears to do little or no harm to the native big game, but causes a deadly disease both in the horses and cattle introduced by Europeans and in the more anciently introduced native cattle (of Indian origin). Similar cases are found where a disease germ (such as that of measles) produces but a small degree of sickness and mortality in a population long associated with it, but is deadly to a human community to which it is a new-comer. Thus Europeans have introduced measles with deadly results in the South Sea Islands. A similar kind of difficulty, of which many might be

some regions exterminated big game, have *per contra* been introduced by man through his importation of diseased animals of his own breeding from Europe. Most, if not all, animals in extra-human conditions, including the minuter things such as insects, shell-fish, and invisible aquatic organisms, have been brought into a condition of 'adjustment' to their parasites as well as to the other conditions in which they live: it is this most delicate and efficient balance of Nature which Man everywhere upsets. A solitary case of a ravaging epidemic constantly recurring amongst animals living in extra-human conditions, one of a strangely interesting character, is the phosphorescent disease of the sand-shrimps or sand-hoppers. This is due to a microscopic parasite, a bacterium, which infests the blood and is phosphorescent, so that the infected sand-hopper has at night the brilliancy of a glow-worm. The disease is deadly, and is common among the sand-hoppers dwelling in the sandy flats of the north coast of France, where it may readily be studied.[1] It has

cited, is brought about by man's importations and exportations of useful plants. He thus brought the Phylloxera to Europe, not realizing before hand that this little parasitic bug, though harmless to the American vine, which puts out new shoots on its roots when the insect injures the old ones, is absolutely deadly to the European vine, which has not acquired the simple but all-important mode of growth by which the American vine is rendered safe. Thus, too, he took the coffee-plant to Ceylon, and found his plantations suddenly devastated by a minute mould, the *Himileia vastatrix*, which had lived very innocently before that in the Cingalese forests, but was ready to burst into rapacious and destructive activity when the new unadjusted coffee-trees were imported by man and presented in carefully crowded plantations to its unrestrained infection.

[1] The phosphorescent disease of the sand-hopper (*Talitrus*) is described by Giard and Billet in a paper entitled 'Observations sur la maladie phosphorescente des Talitres et autres Crustacés,' in the memoirs of the Société de Biologie, Oct. 19, 1889. Billet subsequently

not been recorded as occurring in this country. It is not at all improbable that this disease is also in truth one which only occurs in the trail of Man. It is quite likely that the artificial conditions of sewage and garbage set up by Man on the sea-coast are responsible for the prevalence of this parasite, and the weakly receptivity of the too numerous sand-hoppers.

It is probable enough that, from time to time, under the influence of certain changes of climate and associated fauna and flora—due to meteoric or geologic movements—parasitic disease has for a time ravaged this or that species newly exposed to it; but the final result is one of the alternatives, extinction or adjustment, death or toleration. The disease does not establish itself as a scourge against which the diseased organism incessantly contends. It either obliterates its victim or settles down with it into relations of reciprocal toleration.

Man does not admit this alternative either for himself or for the domesticated and cultivated organisms which he protects. He 'treats' disease, he staves off 'the adjustment by death,' and thus accumulates vast

gave a further account of this organism, and named it *Bacillus Giardi* —after Professor Giard of Paris. (Bulletins scientifiques de la France et de la Belgique, xxi. 1898, p. 144).

It appears that the parasite is transmitted from one individual to another in coition. The specimens studied by Giard and Billet were obtained at Wimereux near Boulogne. I found the disease very abundant at Ouistreham near Caen in the summer of 1900. I have not observed it nor heard of its occurrence on the English coast. Sea-water commonly contains a free-living phosphorescent bacterium which can be cultivated in flasks of liquid food so as to give rich growths which glow like a lamp when the flask is agitated so as to expose the contents to oxidation. This bacterium is not, however, the cause of the 'phosphorescence' of the sea often seen on our coasts. That is due in most cases to a much larger organism, as big as a small pin's head, and known as *Noctiluca miliaris*.

populations of unadjusted human beings, animals and plants, which from time to time are ravaged by disease —producing uncertainty and dismay in human society. Within the past few years the knowledge of the causes of disease has become so far advanced that it is a matter of practical certainty that, by the unstinted application of known methods of investigation and consequent controlling action, all epidemic disease could be abolished within a period so short as fifty years. It is merely a question of the employment of the means at our command. Where there is one man of first-rate intelligence employed in detecting the disease-producing parasites, their special conditions of life and the way to bring them to an end, there should be a thousand. It should be as much the purpose of civilized governments to protect their citizens in this respect as it is to provide defence against human aggression. Yet it is the fact that this immensely important control of a great and constant danger and injury to mankind is left to the unorganized inquiries of a few enthusiasts. So little is this matter understood or appreciated, that those who are responsible for the welfare of States, with the rarest exceptions, do not even know that such protection is possible, and others again are so far from an intelligent view as to its importance, that they actually entertain the opinion that it would be a good thing were there more disease in order to get rid of the weakly surplus population!

In the spring of 1905 I was enabled to examine in the Pasteur Institute in Paris, the minute spiral thread (see Fig. 6) which has just been discovered and shown to be the cause of the most terrible and widely spread of human diseases, destroying the health and strength of those whom it does not kill and damaging the lives of their

children, so that it has been justly said that this malady and the use of alcohol as a beverage are together responsible for more than half the disease and early death of the mature population of Europe. For more than thirty years, a few workers, here and there, have been searching for this parasite, and the means of suppressing the awful curse of which it is the instrument.

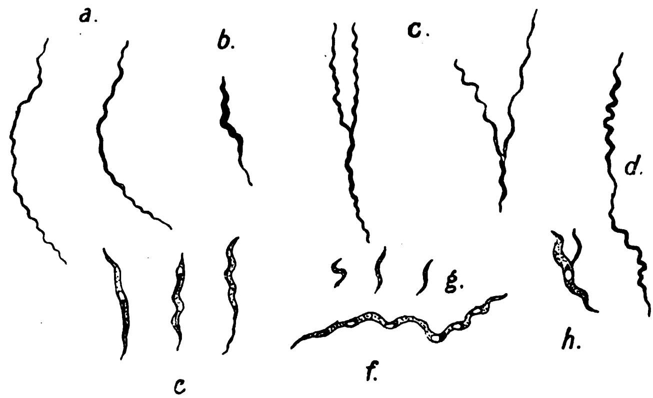


FIG. 6.

The minute vibratile organism discovered by Fritz Schaudinn in 1905 in the eruptive formations and other diseased growths of syphilis—and called by him *Spirochæta pallida* (since altered to *Spironema pallidum*): *a*, common phase; *b*, shortened and thickened form leading on to *e* the Trypanosoma-like form; *c*, *d*, stages of division by fission; *f*, elongated multi-nuclear form; *g*, segments into which it breaks up; *h*, supposed conjugation of male and female units (after Krystallovitch and Siedlevski).

This organism, though resembling the spirillar forms of Bacteria, is probably not one of that group of vegetable parasites, but allied to the minute animal parasites known as Trypanosomes (see pp. 145 and 181 and figures.) It is regarded as the 'germ' or active cause of the terrible disease known as Syphilis.

It would have been discovered many years ago had greater value been set on the inquiries which lead to such discoveries by those who direct the public expenditure of civilized States. And now the complete suppression of this dire enemy of humanity is as plain

and certain a piece of work to be at once accomplished as is the building of an ironclad. But it will not be done for many years because of the ignorance and unbelief of those who alone can act for the community in such matters. The discovery—the presentation to the eye and to exploring manipulation—of that well-nigh ultra-microscopic germ of death, seemed to me, as I gazed at its delicate shape, a thing of greater significance to mankind than the emendation of a Greek text or the determination of the exact degree of turpitude of a statesman of a bygone age.

The knowledge of the causation of disease by bacterial and protozoic parasites is a thing which has come into existence, under our very eyes and hands, within the last fifty years. The parasite, and much of its nature and history, has been discovered in the case of splenic fever, leprosy, phthisis, diphtheria, typhoid fever, glanders, cholera, plague, lock-jaw, gangrene, septic poisoning (of wounds), puerperal fever, malaria, sleeping sickness, and some other diseases which are fatal to man. In some cases the knowledge obtained has led to a control of the attack or of the poisonous action of the parasite. Antiseptic surgery, by defeating the poisonous parasite, has saved not only thousands upon thousands of lives, but has removed an incalculable amount of pain. Control is slowly being obtained in regard to several others among these deadly microbes in various ways, most wonderful of which is the development, under man's control, of serums containing antitoxins appropriate to each disease, which have to be injected into the blood as the means of either cure or protection. But why should we be content to wait long years, even centuries, for this control, when we can have it in a few years? If more men and abler

men were employed to study and experiment on this matter, we should soon make an end of all infectious disease. Is there any one, man or woman, who would not wish to contribute to the removal from human life of the suffering and uncertainty due to disease, the anguish and misery caused by premature death? Yet nothing is done by those who determine the expenditure of the revenues of great States towards dealing adequately with this matter.[1]

[1] As little is the question of the use and abuse of food and drink dealt with, as yet, by civilized man. As in many other matters man has carried into his later crowded, artificial, nature-controlling life habits and tendencies derived from savage prehistoric days, so has he perpetuated ways of feeding which are mere traditions from his early 'animal' days, and have never been seriously called in question and put to proof. The persistence under new conditions of either habit or structure which belonged to old conditions may be attended with great danger and difficulty to an organism which changes, as man does, with great rapidity important features in its general surroundings and mode of life. This is in effect Metschnikoff's doctrine of 'désharmonies.' It is probable that in very early days when a tribe of primitive men killed a mammoth, they all rushed on to the dead monster and gorged as much of its flesh as they could swallow (cooked or possibly uncooked). They had to take in enough to last for another week or two—that is to say, until another large animal should be trapped and slain. Accordingly he who could eat most would be strongest and best able to seize a good share when the next opportunity arrived, and it naturally became considered an indication of strength, vigour, and future prosperity to be capable of gorging large quantities of food. By means of the phrases 'enjoying a good appetite,' or 'a good trencherman,' or other such approving terms, civilized society still encourages the heavy feeder. The lower classes always consider a ravenous appetite to be an indication of strength and future prosperity in a child. Most healthy men, and even many women, in Western Europe, attack their food and swallow it without sufficient mastication, and as though they did not hope to get another chance of feeding for a week or two to come. Medical men have never ventured to investigate seriously whether civilized man is doing best for his health in behaving like a savage about his food. It is their business to attend to the patient with a disordered digestion, but not to experiment upon the amount of food of various kinds which the modern man should swallow in order to avoid indigestion and yet supply his

15. The Increase of Human Population.

Whilst there is a certainty of Man's power to remove all disease from his life, a difficulty which he has already created for himself will be thereby increased. That difficulty is the increase of human population beyond the capacity of the earth's surface to provide food and the other necessities of life. By rebelling against Nature's method, Man has made himself the only animal which constantly increases in numbers. Whenever disease is controlled his increase will be still more rapid than at

alimentary needs. No individual can possibly pay medical men to make these observations. It is the business of the State to do so, because such knowledge is not only needed by the private citizen, but is of enormous importance in the management of armies and navies, in the victualling of hospitals, asylums, and prisons. Thousands of tons of preserved meat have been wasted in recent wars because the reckless and ignorant persons who purchased the preserved meat to feed soldiers had never taken the trouble to ascertain whether preserved meat can be eaten by a body of men as a regular and chief article of diet. It appears that certain methods of preserving meat render it innutritious and impossible as a diet.

It is probable from recent experiment that we all, except those unfortunate few who do not get enough, eat about twice as much as we require, and that the superfluous quantity swallowed not only is wasted, but is actually a cause of serious illness and suffering. It surely is an urgent matter that these questions about food should be thoroughly investigated and settled. In the opinion of the most eminent physiologist of the United States (Professor Bowditch), we shall never establish a rational and healthy mode of feeding ourselves until we give up the barbarous but to some persons pleasant custom of converting the meal into a social function; we are thus tempted into excess. Only long and extensive experiment can provide us with definite and conclusive information on this matter, which is far more important than, at first sight, it seems to be. And similarly with regard to the admittedly serious question of alcohol—only very extensive and authoritative experiment will suffice to show mankind whether it is a wise and healthy thing to take it in small quantities, the exact limits of which must be stated, or to reject it altogether.

present. At the same time no attempt at present has been made by the more advanced communities of civilized men to prevent the multiplication of the weakly or of those liable to congenital disease. Already something like a panic on this subject has appeared in this country. Inquiries have been conducted by public authorities. But the only possible method of dealing with this matter, and in the first place of estimating its importance as immediate or remote, has not been applied. Man can only deal with this difficulty created by his own departure from Nature—to which he can never return—by thoroughly investigating the laws of breeding and heredity, and proceeding to apply a control to human multiplication based upon certain and indisputable knowledge.

It may be a century, or it may be more than five centuries, before the matter would, if let alone, force itself upon a desperate humanity, brutalized by over-crowding, and the struggle for food. A return to Nature's terrible selection of the fittest may, it is conceivable, be in this way in store for us. But it is more probable that humanity will submit, before that condition occurs, to a restriction by the community in respect of the right to multiply, with as good a grace as it has given up the right to murder and to steal. In view of this Man must, in entering on his kingdom, at once proceed to perfect those studies as to the transmission of qualities by heredity which have as yet been only roughly carried out by breeders of animals and horticulturists.

There is absolutely no provision for this study in any civilized community, and no conception among the people or their leaders that it is a matter which concerns any one but farmers.

16. An Untouched Source of Energy.

The applications of steam and electricity have so far astonished and gratified the rebel Man, that he is sometimes disposed to conclude that he has come to the end of his power of relieving himself from the use of his own muscles for anything but refined movements and well-considered health-giving exercises. One of the greatest of chemical discoverers at this time living, M. Berthelot, has, however, recently pressed on our attention the question of the possibility of tapping the central heat of the earth and making use of it as a perennial source of energy. Many competent physicists have expressed the opinion that the mechanical difficulties of such a boring, as would be necessary, are insuperable. No one, however, would venture to prophesy, in such a matter as this, that what is prevented by insuperable obstacles to-day may not be within our powers in the course of a few years.

17. Speculations as to the Martians.

Such audacious control of the resources of our planet is suggested as a possibility, a legitimate hope and aim, by recent observations and speculations as to our neighbour, the planet Mars. I do not venture to express any opinion as to the interpretation of the appearances revealed by the telescope on the surface of the planet Mars, and indeed would take the most sceptical attitude until further information is obtained. But the influence of these statements about Mars on the imagination and hopes of Man seems to me to possess considerable interest. The markings on the surface of the planet Mars, which have been interpreted as a system of canals,

have been known and discussed for many years (see Figs. 7 and 8). It has recently been observed that these canals undergo a recurrent seasonal change of appearance consistent with the hypothesis that they are periodically filled with water, which is derived from the polar snow-caps of the planet at the season of greatest polar heat. It is suggested that Mars is inhabited by an intelligent population, not necessarily closely similar to mankind, but, on the

FIG. 7.

Drawing of Mars in November with Long. 156° on the meridian, shewing the 'Mare Sirenum' (the shaded sickle-shaped area), connected with a network of 'canals' shewing 'spots' or 'oases' at the intersections of the canals and a system of spherical triangles as the form of the meshwork.—*From* 'Mars,' by Perceval Lowell.

contrary unlike mankind in proportion as the conditions of Mars are unlike those of the Earth, and that these inhabitants have constructed by their own efforts the enormous irrigation works upon which the fertility and habitability of their planet, at the present time, depend.

These speculations lead M. Faguet of the French Academy to further reflections. The Martians who have carried out this vast manipulation of a planet must be not only far in advance of the inhabitants of the Earth in intelligence and mechanical power, as a result of the greater age of their planet and the longer continuance there of the evolution of an intelligent race, but such a vast work and its maintenance would seem to imply a complete

Fig. 8.

Drawing of Mars as seen on November 18th, 1894 (Long. 325° on the meridian) by Mr. Perceval Lowell at the Flagstaff Observatory, Arizona, U.S.A., shewing 'twin' or 'double' canals, connected northwards with the 'Mare Icarium.' The two figures here reproduced only give a small portion of the system of canals, oases and seas of the planet Mars, mapped by Mr. Lowell.

unanimity among the Martians, a world-wide peace and common government. Since we can imagine such a result of the prolonged play of forces in Mars, similar to those at work in our own Earth, and even obtain some

slight confirmation of the supposition, may we not indulge in the surmise that some such future is in store for Man, that he may be able hereafter to deal with great planetary factors to his own advantage, and not only draw heat from the bowels of the earth for such purposes as are at present within his scope, but even so as to regulate, at some distant day, the climates of the earth's surface, and the winds and the rain which seem now for ever beyond his control?

18. The Investigation of the Human Mind.

In such a desultory survey as that on which I have ventured, of Man's kingdom and its dangers, it occurs to me to mention another area upon which it seems urgent that the activities of nature-searchers should be immediately turned with increased power and number. The experimental study of his body and of that of animals has been carried far and with valuable results by inquiring Man. But a singularly small amount of attention has as yet been given to the investigation of Man's mind as a natural phenomenon and one which can be better understood to the immense advantage of the race.

The mind of Man—it matters not for my immediate argument whether it be regarded as having arisen normally or abnormally from the mind of animals—is obviously the one and all-powerful instrument with which he has contended, and is destined hereafter to contend, against extra-human Nature. It is no less important for him to know the quality, the capacity, the mode of operation of this instrument, its beginnings and its limitations, than it is for him to know the minutest details of the workings of Nature. Just as much in the

one case as in the other, it is impossible for him to trust to the imperfect analysis made by ancient races of men and the traditions and fancies handed down in old writings—produced by generations who had not arrived at the method of investigation which we now can apply. Experiment upon the mental processes of animals and of Man is greatly needed. Only here and there has anything been done in this direction. Most promising results have been obtained by such observations as those on hypnotism and on various diseased and abnormal states of the brain. But the subject is so little explored that wild and untested assertions as to the powers of the mind are current and have given rise to strange beliefs, accepted by many seriously-intentioned men and women. We boldly operate upon the minds of children in our systems of education without really knowing what we are doing. We blindly assume that the owners of certain minds, traditionally trained in amusing elegancies, are fit to govern their fellow-men and administer vast provinces; we assume that the discovery and comprehension of Nature's processes must be the work of very few and peculiar minds; that if we take care of the body the mind will take care of itself. We know really nothing of the heredity of mental qualities, nor how to estimate their presence or absence in the young so as to develop the mind to greatest advantage. We know the pain and the penalty of muscular fatigue, but we play with the brains of young and old as though they were indestructible machinery. What is called experimental psychology is only in its infancy, but it is of urgent necessity that it should be systematically pursued by the application of public funds in order that Man may know how to make the best use of his only weapon in his struggle to control Nature.

19. Man's Delay: its Cause and Remedy.

Even the slight and rapid review just given of Man's position, face to face with Nature, enables us to see what a tremendous step he has taken, what desperate conditions he has created by the wonderful exercise of his will; how much he has done and can do to control the order of Nature, and how urgent it is, beyond all that words can say, for him to apply his whole strength and capacity to gaining further control, so that he may accomplish his destiny and escape from misery.

It is obvious enough that Man is, at present, doing very little in this direction; so little that one seeks for an explanation of his apathy, his seeming paralysis.

The explanation is that the masses of the people, in civilized as well as uncivilized countries, are not yet aware of the situation. When knowledge on this matter reaches, as it inevitably will in time, to the general population, it is certain that the democracy will demand that those who expend the resources of the community, and as government officials undertake the organization of the national defence and other great public services for the common good, shall put into practice the power of Nature-control which has been gained by mankind, and shall exert every sinew to obtain more. To effect this, the democracy will demand that those who carry on public affairs shall not be persons solely acquainted with the elegant fancies and stories of past ages, but shall be trained in the acquisition of natural knowledge and keenly active in the skilful application of Nature-control to the development of the well-being of the community.

It would not be necessary to wait for this pressure from below were the well-to-do class—which in most

modern States exercises so large an influence both in the actual administration of Governments and by example—so situated as to be in any way aware of the responsibilities which rest upon it. Traditional education has, owing to causes which are not far to seek, deprived the well-to-do class of a knowledge of, and interest in, Man's relation to Nature, and of his power to control natural processes. During the whole period of the growth of man's knowledge of Nature—that is to say, ever since the days of Bruno—the education of the well-to-do has been directed to the acquirement of entertaining information and elegant accomplishments, whilst 'useful knowledge' has been despised and obtained, when considered necessary, from lower-class 'workmen' at workmen's wages. It is of course not to be overlooked that there have been notable exceptions to this, but they have been exceptions. Even at the present day, in some civilized States, a body of clerks, without any pretence to an education in the knowledge of Nature, headed by gentlemen of title, equally ignorant, are entrusted with, and handsomely paid and rewarded for, the superintendence of the armies, the navies, the agriculture, the public works, the fisheries, and even the public education of the State. When compelled to seek the assistance of those who have been trained in the knowledge of Nature (for even in these States there are a few such eccentric persons to be found), the officials demand that such assistance shall be freely given to them without pay, or else offer to buy the knowledge required at the rate paid to a copying clerk.

This state of things is not one for which it is possible to blame those who, in blissful ignorance, contentedly perform what they consider to be their duty to their country. There are, however, in many States, institu-

tions, of vast influence in the education of the whole community, known as Universities. In many countries they as well as the schools are directly controlled by the State. In England, however, we are happy in having free Universities, the older of which, though in some important respects tied down by law, yet have the power to determine almost absolutely, not only what shall be studied within their own walls, but what shall be studied in all the schools of the country frequented by the children of the well-to-do.

It is the pride of our ancient Universities that they are largely, if not exclusively, frequented by young men of the class who are going to take an active part in the public affairs of the country—either as politicians and statesmen, as governors of remote colonies, or as leaders of the great professions of the Church, the Law, and Medicine. It would seem, then, that if these Universities attached a greater, even a predominant, importance to the studies which lead to the knowledge and control of Nature, the schools would follow their example, and that the governing class of the country would become acquainted with the urgent need for more knowledge of the kind, and for the immediate application in public affairs of that knowledge which exists.

It would seem that in Great Britain, at any rate, it would not be necessary, were the Universities alive to the situation, to await the pressure of democracy, but that a better and more rapid mode of development would obtain; the influential and trusted leaders of the community would set the example in seeking and using for the good of the State the new knowledge of Nature. The world has seen with admiration and astonishment the entire people of Japan follow the example of its

governing class in the almost sudden adoption of the knowledge and control of Nature as the purpose of national education and the guide of State administration. It is possible that in a less rapid and startling manner our old Universities may, at no distant date, influence the intellectual life of the more fortunate of our fellow citizens, and consequently of the entire community. The weariness which is so largely expressed at the present day in regard to human effort—whether it be in the field of politics, of literature, or of other art, or in relation to the improvement of social organization and the individual life—is possibly due to the fact that we have exhausted the old sources of inspiration, and have not yet learnt to believe in the new. The 'return to Nature,' which is sometimes vaguely put forward as a cure for the all-pervading 'taedium' of this age, is perhaps an imperfect expression of the truth that it is time for civilized man not to return to the 'state of Nature,' but to abandon his retrospective attitude and to take up whole-heartedly the Kingdom of Nature which it is his destiny to rule. New hope, new life will, when he does this, be infused into every line of human activity: Art will acquire a new impulse, and politics become real and interesting. To a community which believes in the destiny of Man as the controller of Nature, and has consciously entered upon its fulfilment, there can be none of the weariness and even despair which comes from an exclusive worship of the past. There can only be encouragement in every victory gained, hope and the realization of hope. Even in the face of the overwhelming opposition and incredulity which now unhappily have the upper hand, the believer in the predestined triumph of Man over Nature can exert himself to place a contribution, however small, in

the great edifice of Nature-knowledge, happy in the conviction that his life has been worth living, has counted to the good in the imperishable result.

20. The Influence of Oxford.

If I venture now to consider more specifically the influence exercised by the University of Oxford upon the welfare of the State and of the human community in general, in view of the conclusions which have been set forth in what has preceded, I beg to say that I do so with the greatest respect to the opinions of others who differ from me. When I say this I am not using an empty formula. I mean that I believe that there must be many University men who are fair-minded and disinterested, and have given special attention to the matter of which I wish to speak, and who are yet very far from agreeing with me. I ask them to consider what I have said, and what I have further to say, in the same spirit as that in which I approach them.

It seems to me—and when I speak of myself I would point out that I am presenting the opinions of a large number of educated men, and that it will be better for me to avoid an egotistical attitude—it seems to us (I prefer to say) that the University of Oxford by its present action in regard to the choice and direction of subjects of study is exercising an injurious influence upon the education of the country, and especially upon the education of those who will hereafter occupy positions of influence, and will largely determine both the action of the State and the education and opinions of those who will in turn succeed them. The question has been recently raised as to whether the acquirement of a certain elementary knowledge of the Greek language

should be required of all those who desire to pursue their studies in this University, and accordingly whether the teaching of the elements of this language should form a prominent feature in the great schools of this country. It seems to us that this is only part of a much larger question; namely, whether it is desirable to continue to make the study of two dead languages—and of the story of the deeds of great men in the past—the main if not the exclusive matter to which the minds of the youth of the well-to-do class are directed by our schools and universities. We have come to the conclusion that this form of education is a mistaken and injurious one. We desire to make the chief subject of education both in school and in college a knowledge of Nature as set forth in the sciences which are spoken of as physics, chemistry, geology, and biology. We think that all education[1] should consist in the first place of this kind of knowledge, on account of its commanding importance both to the individual and to the community. We think that every man of even a moderate amount of education should have acquired a sufficient knowledge of these subjects to enable him at any rate to appreciate their value, and to take an interest in their progress and application to human life. And we think further that the ablest youths of the country should be encouraged to proceed to the extreme limit

[1] It is, perhaps, needful to point out that what is aimed at is that the education of all the youth of the country, both of pass-men and of class-men, of girls as well as of boys, of the rich as well as of the poor, should be primarily directed to imparting an acquaintance with what we already possess in respect of knowledge of Nature, and the training of the pupil so as to enable him or her (*a*) to make use of that knowledge, and (*b*) to take part in gaining new knowledge of Nature, at this moment needed but non-existent. This does not involve the complete exclusion of other subjects of instruction, to which about one-third of the time and effort of school and college life might be devoted.

of present knowledge in one or other branch of this knowledge of Nature so as to become makers of new knowledge, and the possible discoverers of enduring improvements in man's control of Nature. No one should be educated so as to be ignorant of the importance of these things; and it should not be possible for the greatest talent and mental power to be diverted to other fields of activity through the fact that the necessary education and opportunity in the pursuit of the knowledge of Nature are withheld. The strongest inducements in the way of reward and consideration ought, we believe, to be placed before a young man in the direction of Nature-knowledge rather than in the direction of other and far less important subjects of study.

In fact, we should wish to see the classical and historical scheme of education entirely abandoned, and its place taken by a scheme of education in the knowledge of Nature.

At the same time let me hasten to say that few, if any of us—and certainly not he who writes these lines—would wish to remove the acquirement of the use of languages, the training in the knowledge and perception of beauty in literary art, and the feeding of the mind with the great stories of the past, from a high and necessary position in every grade of education.

It is a sad and apparently inevitable accompaniment of all discussion of this matter that those who advocate a great and leading position for the knowledge of Nature in education are accused of desiring to abolish all study of literature, history, and philosophy. This is, in reality, so far from being the case that we should most of us wish to see a serviceable knowledge of foreign languages, and a real acquaintance with the beauties of English and other literature, substituted for the present

unsuccessful efforts to teach effectively either the language or literature of the Greeks and Romans.

It should not be for one moment supposed that those who attach the vast importance which we do to the knowledge of Nature imagine that Man's spirit can be satisfied by exclusive occupation with that knowledge. We know, as well as any, that Man does not live by bread alone. Though the study of Nature is fitted to develop great mental qualities—perseverance, honesty, judgement, and initiative—we do not suppose that it completes Man's mental equipment. Though the knowledge of Nature calls upon, excites, and gratifies the imagination to a degree and in a way which is peculiar to itself, we do not suppose that it furnishes the opportunity for all forms of mental activity. The great joys of Art, the delights and entertainment to be derived from the romance and history of human character, are not parts of it. They must never be neglected. But are we not justified in asserting that, for some two hundred years or more, these 'entertainments' have been pursued in the name of the highest education and study to the exclusion of the far weightier and more necessary knowledge of Nature? 'This should ye have done, and yet not left the other undone,' may justly be said to those who have conducted the education of our higher schools and universities along the pleasant lines of literature and history, to the neglect of the urgently-needed 'improvement of Natural Knowledge.' Nero was probably a musician of taste and training, and it was artistic and high-class music which he played while Rome was burning: so too the studies of the past carried on at Oxford have been charming and full of beauty, whilst England has lain, and lies, in mortal peril for lack of knowledge of Nature.

It seems to be beyond dispute that the study, firstly of Latin, and much more recently of Greek, were followed in our Universities and in grammar schools, not as educational exercises in the use of language, but as keys to unlock the store-rooms—the books—in which the knowledge of the ancients was contained. So long as these keys were needed, it was reasonable enough that every well-educated man should spend such time as was necessary in providing himself with the key. But now that the store-rooms are empty—now that their contents have been appropriated and scattered far and wide—in all languages of civilization, it seems to be merely an unreasoning continuation of superannuated custom to go on with the provision of these keys. Such, however, is the force of habit that it continues: new and ingenious reasons for the practice are put forward, whilst its original object is entirely forgotten.

In the first place, it has come to be regarded as a mark of good breeding, and thus an end in itself, for a man to have some first-hand acquaintance with Latin and Greek authors, even when he knows no other literature. It is a fashion, like the wearing of a court dress. This cannot be held to justify the employment of most of the time and energy of youth in its acquirement.

A second reason which is now put forward for the practice is that the effort and labour expended on the provision of these keys—even though it is admitted that they are useless—are a wonderful and incomparably fine exercise of the mind, fitting it for all sorts of work. A theory of education has been enunciated which fits in with this defence of the continued attempt to compel young men to acquire a knowledge, however imperfect, of the Latin and Greek languages. It is

held that what is called 'training the mind' is the chief, if not the only proper, aim of education; and it is declared that the continuation of the study of those once useful, but now useless, keys—Latin and Greek—is an all-sufficient training. If this theory were in accordance with the facts, the conclusion in favour of giving a very high place to the study so recommended would be inevitable. But the facts do not support this theory. Clever youths are taken and pressed into the study of Greek and Latin, and we are asked to conclude that their cleverness is due to these studies. On the other hand, we maintain that though the study of grammar may be, when properly carried out, a valuable exercise, yet that it is easily converted into a worthless one, and can never in any case take the place of various other forms of mental training, such as the observation of natural objects, the following out of experimental demonstration of the qualities and relations of natural bodies, and the devising and execution of experiment as the test of hypothesis. Apart from 'training' there is the need for providing the mind with information as well as method. The knowledge of Nature is eagerly assimilated by young people, and no training in mental gymnastics can be a substitute for it or an excuse for depriving the young of what is of inestimable value and instinctively desired.

The prominence which is assigned to a familiarity with the details of history, more especially of what may be called biographical history, in the educational system favoured by Oxford, seems to depend on the same causes as those which have led to the maintenance of the study of Greek and Latin. To read history is a pleasant occupation which has become a habit

and tradition. At one time men believed that history repeats itself, and it was thought to be a proper and useful training for one who would take part in public affairs to store his mind with precedents and picturesque narratives of prominent statesmen and rulers in far-off days and distant lands. As a matter of fact it cannot be shown that any statesman, or even the humblest politician, has ever been guided to useful action by such knowledge. History does not repeat itself, and the man who thinks that it does will be led by his fragmentary knowledge of stories of the past into serious blunders. To the fashionable journalist such biographical history furnishes the seasoning for his essays on political questions of the day. But this does not seem to be a sufficient reason for assigning so prominent a place in University studies to this kind of history as is at present the case. The reason, perhaps, of the favour which it receives, is that it is one of the few subjects which a man of purely classical education can pursue without commencing his education in elementary matters afresh.

It would be a serious mistake [1] to suppose that those who would give a complete supremacy to the study of Nature, in our educational system, do not value and enjoy biographical history for what it is worth as an entertainment; or further, that they do not set great value upon the scientific study of the history of the struggles of the races and nations of mankind, as a portion of the knowledge of the evolution of Man, capable of giving conclusions of great value when it has been further and more thoroughly treated as a

[1] I desire especially to draw the attention of those who have misunderstood and misrepresented my estimate of the importance of the study of History, to this paragraph.—E.R.L.

department of Anthropology. What seems to us undesirable is, that mere stories and bald records of certain peoples should be put forward as matter with which the minds of children and young men are to be occupied, to the exclusion of the all-important matters comprised in the knowledge of Nature.

There are, it is well known, not a few who regard the present institution of Latin and Greek and so-called History, in the pre-eminent place which they occupy in Oxford and the great schools of the country, as something of so ancient and fundamental a character that to question the wisdom of that institution seems an odious proceeding, partaking of the nature of blasphemy. This state of mind takes its origin in a common error, due to the fact that a straightforward account of the studies pursued in the University during the last five hundred years has never been written. Our present curriculum is a mere mushroom growth of the last century, and has no claim whatever to veneration. Greek was studied by but a dozen or two specialists in Oxford two hundred and fifty years ago. In those days, in proportion to what had been ascertained in that subject and could be taught, there was a great and general interest in the University in the knowledge of Nature, such as we should gladly see revived at the present day. As a matter of fact, it is only within the last hundred years that the dogma of compulsory Greek, and the value of what is now called a classical education, has been promulgated. These things are not historically of ancient date; they are not essentials of Oxford. We are therefore well within our right in questioning the wisdom of their continuance in so favoured a position, and we are warranted in expressing the hope that those who can change the

policy of the University and Colleges in this matter will, at no distant day, do so.

It is sometimes urged that Oxford should contentedly resign herself to the overwhelming predominance given to the study of ancient elegance and historic wisdom within her walls. It is said that she may well be reserved for these delightful pursuits, whilst newer institutions should do the hard work of aiding man in his conquest of Nature. At first sight such a proposal has a tempting character: we are charmed with the suggestion that our beautiful Oxford should be enclosed by a ring fence and cut off for ever from the contamination of the world. But a few moments' reflection must convince most of us that such a treatment of Oxford is an insult to her and an impossibility. Oxford is not dead. Only a few decades have passed—a mere fraction of her lifetime—since she was free from the oppression of grammar-school studies, and sent forth Robert Boyle and Christopher Wren to establish the New Philosophy of the Invisible College in London. She seems, to some of us, to have been used not quite wisely, perhaps not quite fairly, in the brief period which has elapsed since that time. Why should she not shake herself free again, and give, hereafter, most, if not the whole, of her wealth and strength to the urgent work which is actually pursued in every other University of the world as a chief aim and duty?

The fact that Oxford attracts the youth of the country to her, and so determines the education offered in the great schools, is a sufficient answer to those who wish to perpetuate the present employment of her resources in the subvention and encouragement of comparatively unimportant, though fascinating (even too fascinating), studies, to the neglect of the pressing

necessary knowledge of Nature. Those who enjoy great influence in the affairs of the University tell us with pride that Oxford not only determines what our best schools shall teach, but has, as a main pre-occupation, the education of statesmen, pro-consuls, leaders of the learned professions, and members of parliament! Undoubtedly this claim is well-founded, and its truth is the reason why we cannot be content with the maintenance by the University of the compulsory study of Greek and Latin, and the neglect to make the study of Nature an integral and predominant part of every man's education.

To return to my original contention—the knowledge and control of Nature is Man's destiny and his greatest need. To enable future leaders of the community to comprehend this, to perceive what the knowledge and control of Nature are, and what are the steps by which they are gained and increased, is the duty of a great University. To neglect this is to retard the approach of well-being and happiness, and to injure humanity.

I beg, finally, for toleration from those who do not share my opinions. I am well aware that they are open to the objection that they partake more of the nature of dreams of the future than of practical proposals.[1] That,

[1] The practical steps which would correspond to the views enunciated in this discourse are two. First, the formation of an educational association to establish one or more schools and colleges in which nature-knowledge and training in nature-searching should be the chief matters to which attention would be given, whilst reasonable methods would also be employed for implanting in the minds of the students a love and understanding of literature and other forms of art. Those who desired such an education for their children would support these schools and colleges, just as in the days of Anglican exclusiveness the Nonconformists and Roman Catholics supported independent educational institutions. The second practical step would be the formation of a political union which would make due respect to efficiency, that is

perhaps, may be accepted as my excuse for indulging in them. There are, and always have been, dreamers in Oxford, and beautiful dreams they have dreamed—some of the past, and some of the future. The most fascinating dreams are not, unfortunately, always realized; but it is sometimes worth while to tell one's dream, for that may bring it a step nearer to 'coming true.'

to say, to a knowledge of Nature, a test question in all political contests. No candidate for Parliament would receive the votes of the union unless he were either himself educated in a knowledge of Nature or promised his support exclusively to ministers who would insist on the utilization of nature-knowledge in the administration of the great departments of State, and would take active measures of a financial character to develop with far greater rapidity and certainty than is at present the case, that inquiry into and control of Nature which is the indispensable factor in human welfare and progress. Such a programme will, I hope, at no distant date obtain the support of a sufficient number of parliamentary voters to raise political questions of a more genuine and interesting character than those which many find so tedious at the present moment.

APPENDIX.

I add here a brief statement published by me in the Times, *May 17th,* 1903, *which touches on the question of the origin of life, and certain theories of creation.*

"It seems to me that, were the discussion excited by Lord Kelvin's statements to the Christian Association at University College allowed to close in its present phase, the public would be misled and injustice done both to Lord Kelvin and his critics. I therefore beg you to allow me to point out what appear to me to be the significant features of the matter under discussion.

"Lord Kelvin, whose eminence as a physicist gives a special interest to his opinion upon any subject, made at University College, or in his subsequent letter to you, the following statements:—

"1. That 'fortuitous concourse of atoms' is not an inappropriate description of the formation of a crystal.

"2. That 'fortuitous concourse of atoms' is utterly absurd in respect to the coming into existence, or the growth, or the continuation of the molecular combinations presented in the bodies of living things.

"3. That, though inorganic phenomena do not do so, yet the phenomena of such living things as a sprig of moss, a microbe, a living animal—looked at and considered as matters of scientific investigation—compel us to conclude that there is scientific reason for believing in the existence of a creative and directive power.

"4. That modern biologists are coming once more to a firm acceptance of something, and that is—a vital principle.

"In your article on the discussion which has followed these statements you declare that this (the opinions I have quoted above) is 'a momentous conclusion,' and that it is a vital point in the relation of science to religion.

"I do not agree with that view of the matter, although I find Lord Kelvin's statements full of interest. So far as I have been able to ascertain, after many years in which these matters have engaged my attention, there is no relation, in the sense of a connection or influence, between science and religion. There is, it is true, often an antagonistic relation between exponents of science and exponents of religion when the latter illegitimately misrepresent or deny the conclusions of scientific research or try to prevent its being carried on, or, again, when the former presume, by magnifying the extremely limited conclusions of science, to deal in a destructive spirit with the very existence of those beliefs and hopes which are called 'religion.' Setting aside such excusable and purely personal collisions between rival claimants for authority and power, it appears to me that science proceeds on its path without any contact with religion, and that religion has not, in its essential qualities, anything to hope for, or to fear from, science.

"The whole order of nature, including living and lifeless matter—from man to gas—is a network of mechanism the main features and many details of which have been made more or less obvious to the wondering intelligence of mankind by the labour and ingenuity of scientific investigators. But no sane man has ever pretended, since science became a definite body of doctrine, that we know or ever can hope to know or conceive of the possibility of knowing, whence this mechanism has come, why it is there, whither it is going, and what there may or may not be beyond and beside it which our senses are incapable of appreciating. These things are not 'explained' by science, and never can be.

"Lord Kelvin speaks of a 'fortuitous concourse of atoms,' but I must confess that I am quite unable to apprehend what he means by that phrase in the connection in which he uses it. It seems to me impossible that by 'fortuitous' he can mean something which is not determined by natural cause and therefore is not part of the order of nature. When an ordinary man speaks of a concourse having arisen 'by chance' or 'fortuitously,' he means merely that the determining conditions which have led by natural causation to its occurrence were not known to him beforehand; he does not mean to assert that it has

arisen without the operation of such determining conditions; and I am quite unable to understand how it can be maintained that 'the concourse of atoms' forming a crystal, or even a lump of mud, is in any philosophic sense more correctly described as 'fortuitous' than is the concourse of atoms which has given rise to a sprig of moss or an animal. It would be a matter of real interest to many of your readers if Lord Kelvin would explain more precisely what he means by the distinction which he has, somewhat dogmatically, laid down between the formation of a crystal as 'fortuitous' and the formation of an organism as due to 'creative and directive purpose.'

"I am not misrepresenting what Lord Kelvin has said on this subject when I say that he seems to have formed the conception of a creator who, first of all, without care or foresight, has produced what we call 'matter,' with its necessary properties, and allowed it to aggregate and crystallise as a painter might allow his pigments to run and intermingle on his palette; and then, as a second effort, has brought some of these elements together with 'creative and directive purpose,' mixing them, as it were, with 'a vital principle' so as to form living things, just as the painter might pick out certain colours from his confused palette and paint a picture.

"This conception of the intermittent action of creative power and purpose does not, I confess, commend itself to me. That, however, is not so surprising as that it should be thought that this curious conception of the action of creative power is of value to religion. Whether the intermittent theory is a true or an erroneous conception seems to me to have nothing to do with 'religion' in the large sense of that word so often misused. It seems to me to be a kind of mythology, and I should have thought could be of no special assistance to teachers of Christianity. Such theories of divided creative operations are traceable historically to polytheism.

"Lastly, with reference to Lord Kelvin's statement that 'modern biologists are coming once more to a firm acceptance of something—and that is "a vital principle."' I will not venture to doubt that Lord Kelvin has such persons among his acquaintance. On the other hand, I feel some confidence in stating that a more extensive acquaintance with modern biolo-

gists would have led Lord Kelvin to perceive that those whom he cites are but a trifling percentage of the whole. I do not myself know of any one of admitted leadership among modern biologists who is showing signs of 'coming to a belief in the existence of a vital principle.'

"Biologists were, not many years ago, so terribly hampered by these hypothetical entities—'vitality,' 'vital spirits,' 'anima animans,' 'archetypes,' 'vis medicatrix,' 'providential artifice,' and others which I cannot now enumerate—that they are very shy of setting any of them up again. Physicists, on the other hand, seem to have got on very well with their problematic entities, their 'atoms' and 'ether,' and 'the sorting demon of Maxwell.' Hence, perhaps, Lord Kelvin offers to us, with a light heart, the hypothesis of a 'a vital principle' to smooth over some of our admitted difficulties. On the other hand, we biologists, knowing the paralysing influence of such hypotheses in the past, are as unwilling to have anything to do with 'a vital principle,' even though Lord Kelvin erroneously thinks we are coming to it, as we are to accept other strange 'entities' pressed upon us by other physicists of a modern and singularly adventurous type. Modern biologists (I am glad to be able to affirm) do not accept the hypothèsis of 'telepathy' advocated by Sir Oliver Lodge, nor that of the intrusions of disembodied spirits pressed upon them by others of the same school.

"We biologists take no stock in these mysterious entities. We think it a more helpful method to be patient and to seek by observation of, and experiment with, the phenomena of growth and development to trace the evolution of life and of living things without the facile and sterile hypothesis of 'a vital principle.' Similarly, we seek by the study of cerebral disease to trace the genesis of the phenomena which are supposed by some physicists who have strayed into biological fields to justify them in announcing the 'discovery' of 'telepathy' and a belief in ghosts."

CHAPTER II

THE ADVANCE OF SCIENCE, 1881–1906

I PROPOSE to give in the following pages an outline of the advance of science in the past twenty-five years. It is necessary to distinguish two main kinds of advancement, both of which are important. Francis Bacon gave the title 'Advancement of Learning' to that book in which he explained not merely the methods by which the increase of knowledge was possible, but advocated the promotion of knowledge to a new and influential position in the organization of human society. His purpose, says Dean Church, was 'to make knowledge really and intelligently the interest, not of the school or the study or the laboratory only, but of society at large.' So that in surveying the advancement of science in the past quarter of a century we should ask not only what are the new facts discovered, the new ideas and conceptions which have come into activity, but what progress has science made in becoming really and intelligently the interest of society at large. Is there evidence that there is an increase in the influence of science on the lives of our fellow-citizens and in the great affairs of the State? Is there an increased provision for securing the progress of scientific investigation in proportion to the urgency of its need or an increased disposition to secure the employment of really competent men trained in scientific investigation for the public service?

I. The Increase of Knowledge in the Several Branches of Science.

The boundaries of my own understanding and the practical consideration of what is appropriate to a brief essay must limit my attempt to give to the general reader some presentation of what has been going on in the workshops of science in this last quarter of a century. My point of view is essentially that of the naturalist, and in my endeavour to speak of some of the new things and new properties of things discovered in recent years I find it is impossible to give any systematic or detailed account of what has been done in each division of science. All that I shall attempt is to mention some of the discoveries which have aroused my own interest and admiration. I feel, indeed, that it is necessary to ask forbearance for my presumption in daring to treat of so many subjects in which I cannot claim to speak as an authority, but only as a younger brother full of fraternal pride and sympathy in the glorious achievements of the great experimentalists and discoverers of our day.

As one might expect, the progress of the Knowledge of Nature (for it is to that rather than to the historical, moral and mental sciences that English-speaking people refer when they use the word 'science') has consisted, in the last twenty-five years, in the amplification and fuller verification of principles and theories already accepted, and in the discovery of hitherto unknown things which either have fallen into place in the existing scheme of each science or have necessitated new views, some not very disturbing to existing general conceptions, others of a more startling and, at first sight, disconcerting character. Nevertheless I think I am justified in saying

that, exciting and of entrancing interest as have been some of the discoveries of the past few years, there has been nothing to lead us to conclude that we have been on the wrong path—nothing which is really revolutionary; that is to say, nothing which cannot be accepted by an intelligible modification of previous conceptions. There is, in fact, continuity and healthy evolution in the realm of science. Whilst some onlookers have declared to the public that science is at an end, its possibilities exhausted, and but little of the hopes it raised realised, others have asserted on the contrary, that the new discoveries—such as those relating to the X-rays and to radium—are so inconsistent with previous knowledge as to shake the foundations of science, and to justify a belief in any and every absurdity of an unrestrained fancy. These two reciprocally destructive accusations are due to a class of persons who must be described as the enemies of science. Whether their attitude is due to ignorance or traditions of self-interest, such persons exist. It is one of the objects of our scientific associations and societies to combat those assertions and to demonstrate, by the discoveries announced at their meetings and the consequent orderly building up of the great fabric of 'natural knowledge,' that Science has not come to the end of her work—has, indeed, only as yet given mankind a foretaste of what she has in store for it—that her methods and her accomplished results are sound and trustworthy, serving with perfect adaptability for the increase of true discovery and the expansion and development of those general conceptions of the processes of nature at which she aims.

New Chemical Elements.—There can be no doubt that the past quarter of a century will stand out for

ever in human history as that in which new chemical elements, not of an ordinary type, but possessed of truly astounding properties, were made known with extraordinary rapidity and sureness of demonstration. Interesting as the others are, it is the discovery of radio-activity and of the element radium which so far exceeds all others in importance that we may well account it a supreme privilege that it has fallen to our lot to live in the days of this discovery. No single discovery ever made by the searchers of nature even approaches that of radio-activity in respect of the novelty of the properties of matter suddenly revealed by it. A new conception of the structure of matter is necessitated and demonstrated by it, and yet, so far from being destructive and disconcerting, the new conception fits in with, grows out of, and justifies the older schemes which our previous knowledge has formulated.

Before saying more of radio-activity, which is apt to eclipse in interest every other topic of discourse, I must recall to you the discovery of the five inert gaseous elements by Rayleigh and Ramsay, which belongs to the period on which we are looking back. It was found that nitrogen obtained from the atmosphere invariably differed in weight from nitrogen obtained from one of its chemical combinations; and thus the conclusion was arrived at by Rayleigh that a distinct gas is present in the atmosphere, to the extent of 1 per cent., which had hitherto passed for nitrogen. This gas was separated, and to it the name argon (the lazy one) was given, on account of its incapacity to combine with any other element. Subsequently this argon was found by Ramsay to be itself impure, and from it he obtained three other gaseous elements equally inert: namely neon, krypton, and xenon. These were all distinguished

from one another by the spectrum, the sign-manual of an element given by the light emitted in each case by the gas when in an incandescent condition. A fifth inert gaseous element was discovered by Ramsay as a constituent of certain minerals which was proved by its spectrum to be identical with an element discovered twenty-five years ago by Sir Norman Lockyer in the atmosphere of the sun, where it exists in enormous quantities. Lockyer had given the name 'helium' to this new solar element, and Ramsay thus found it locked up in certain rare minerals in the crust of the earth.

But by helium we are led back to radium, for it has been found only two years ago by Ramsay and Soddy that helium is actually formed by a gaseous emanation from radium. Astounding as the statement seems, yet that is one of the many unprecedented facts which recent study has brought to light. The alchemist's dream is, if not realised, at any rate justified. One element is actually under our eyes converted into another; the element radium decays into a gas which changes into another element, namely helium.

Radium, this wonder of wonders, was discovered owing to the study of the remarkable phosphorescence, as it is called—the glowing without heat—of glass vacuum-tubes through which electric currents are made to pass. Crookes, Lenard, and Röntgen each played an important part in this study, showing that peculiar rays or linear streams of at least three distinct kinds are set up in such tubes—rays which are themselves invisible, but have the property of making glass or other bodies which they strike glow with phosphorescent light. The celebrated Röntgen rays make ordinary glass give out a bright green light; but they pass through it, and

cause phosphorescence outside in various substances, such as barium platino-cyanide, calcium tungstate, and many other such salts; they also act on a photographic plate and discharge an electrified body such as an electroscope. But the most remarkable feature about them is their power of penetrating substances opaque to ordinary light. They will pass through thin metal plates or black paper or wood, but are stopped by more or less dense material. Hence it has been possible to obtain 'shadow pictures' or skiagraphs by allowing the invisible Röntgen rays to pass through a limb or even a whole animal, the denser bone stopping the rays, whilst the skin, flesh, and blood let them through. They are allowed to fall (still invisible) on to a photographic plate, when a picture like an ordinary permanent photograph is obtained by their chemical action, or they may be made to exert their phosphorescence-producing power on a glass plate covered with a thin coating of a phosphorescent salt such as barium platino-cyanide, when a temporary picture in light and shade is seen.

The rays discovered by Röntgen were known as the X-rays, because their exact nature was unknown. Other rays studied in the electrified vacuum-tubes are known as cathode rays or radiant corpuscles, and others, again, as the Lenard rays.

It occurred to M. Henri Becquerel, as he himself tells us, to inquire whether other phosphorescent bodies besides the glowing vacuum-tubes of the electricians' laboratory can emit penetrating rays like the X-rays. I say 'other phosphorescent bodies,' for this power of glowing without heat—of giving out, so to speak, cold light—is known to be possessed by many mineral substances. It has become familiar to the public in the form of 'phosphorescent paint,' which contains sulphide of calcium, a

substance which shines in the dark after exposure to sunlight—that is to say, is phosphorescent. Other sulphides and the minerals fluor-spar, apatite, some gems, and, in fact, a whole list of substances have, under different conditions of treatment, this power of phosphorescence or shining in the dark without combustion or chemical change. All, however, require some special treatment, such as exposure to sunlight or heat or pressure, to elicit the phosphorescence, which is of short duration only. Many of the compounds of a somewhat uncommon metallic element, called uranium, used for giving a fine green colour to glass, are phosphorescent substances, and it was, fortunately, one of them which Henri Becquerel chose for experiment. Henri Becquerel is professor in the Jardin des Plantes of Paris; his laboratory is a delightful old-fashioned building, which had for me a special interest and sanctity when, a few years ago, I visited him there, for, a hundred years before, it was the dwelling-house of the great Cuvier. Here Henri Becquerel's father and grandfather—men renowned throughout the world for their discoveries in mineralogy, electricity, and light—had worked, and here he had himself gone almost daily from his earliest childhood. Many an experiment bringing new knowledge on the relations of light and electricity had Henri Becquerel carried out in that quiet old-world place before the day on which, about twelve years ago, he made the experimental inquiry, 'Does uranium give off penetrating rays like Röntgen rays?' He wrapped a photographic plate in black paper, and on it placed and left lying there for twenty-four hours some uranium salt. He had placed a cross, cut out in thin metallic copper, under the uranium powder, so as to give some shape to the photographic print should one be produced. It *was* produced. Penetrating rays

were given off by the uranium: the black paper was penetrated, and the form of the copper cross was printed on a dark ground (fig. 9). The copper was also penetrated to some extent by the rays from the uranium, so that its image was not left actually white. Only one step more remained before Becquerel made his great discovery. It was known, as I stated just now, that sulphide of calcium and similar substances *become* phosphorescent when exposed to sunlight, and lose this phosphorescence after a few hours. Becquerel thought at first that perhaps the uranium salt acquired its power similarly by exposure to light; but very soon, by experimenting with uranium

FIG. 9.—HENRI BECQUEREL'S DISCOVERY OF RADIO-ACTIVITY.

Photographic print or skiagraph of a copper Maltese Cross produced by uranium salt placed as a heap of powder on the surface of black paper wrapped round a sensitive plate. Between the paper and the uranium powder the flat copper cross was interposed. The rays from the uranium salt have penetrated the black paper, but have been intercepted to a large extent by the copper cross—so that the sensitive silver plate is darkened all about the cross—over an area corresponding to that of the heap of uranium salt, but is left pale where the copper figure blocked the path of the active rays given off by the uranium, partially but not wholly. It was thus proved that the rays from the uranium salt can pass through blackened paper and also though to a less extent through a plate of copper.

salt long kept in the dark, he found that the emission of penetrating rays, giving photographic effects, was produced spontaneously. The emission of rays by this

particular sample of uranium salt has shown no sign of diminution since this discovery. The emission of penetrating rays by uranium was soon found to be independent of its phosphorescence. Phosphorescent bodies, as such, do not emit penetrating rays. Uranium compounds, whether phosphorescent or not, emit and continue to emit, these penetrating rays, capable of passing through black paper and in a less degree through metallic copper. They do not derive this property from the action of light or any other treatment. The emission of these rays discovered by Becquerel is a new property of matter. It is called 'radio-activity,' and the rays are called Becquerel rays.

From this discovery by Becquerel to the detection and separation of the new element radium is an easy step in thought, though one of enormous labour and difficulty in practice. Professor Pierre Curie (whose name I cannot mention without expressing the grief caused to all men of science by the sad accident by which his life was taken) and his wife, Madame Sklodowski Curie, incited by Becquerel's discovery, examined the ore called pitch-blende which is worked in mines in Bohemia and is found also in Cornwall. It is the ore from which all commercial uranium is extracted. The Curies found that pitch-blende has a radio-activity four times more powerful than that of metallic uranium itself. They at once conceived the idea that the radio-activity of the uranium salts examined by Becquerel is due not to the uranium itself, but to another element present with it in variable quantities. This proved to be in part true. The refuse of the first processes by which in the manufacturer's works the uranium is extracted from its ore, pitch-blende, was found to contain four times more of the radio-active matter than does the pure uranium.

By a long series of fusions, solutions, and crystallizations the Curies succeeded in 'hunting down,' as it were, the radio-active element. The first step gave them a powder mixed with barium chloride, and having 2,000 times the activity of the uranium in which Becquerel first proved the existence of the new property—radio-activity. Then step by step they purified it to a condition 10,000 times, then to 100,000 times, and finally to the condition of a crystalline salt having 1,800,000 times the activity of Becquerel's sample of uranium. The purification could go no further, but the extraordinary minuteness of the quantity of the pure radio-active substance obtained and the amount of labour and time expended in preparing it may be judged of from the fact that of one ton of the pitch-blende ore submitted to the process of purification only the hundredth of a gram—the one-seventh of a grain—remained.

The amount of radium in pitch-blende is one ten-millionth per cent.; rarer than gold in sea-water. The marvel of this story and of all that follows consists largely in the skill and accuracy with which our chemists and physicists have learnt to deal with such infinitesimal quantities, and the gigantic theoretical results which are securely posed on this pin-point of substantial matter.

The Curies at once determined that the minute quantity of colourless crystals they had obtained was the chloride of a new metallic element with the atomic weight 225, to which they gave the name radium. The proof that radium is an element is given by its 'sign-manual'—the spectrum which it shows to the observer when in the incandescent state. It consists of six bright lines and three fainter lines in the visible part of the spectrum, and of three very intense lines in the ultra-violet (invisible) part (fig. 10). A very minute quantity is

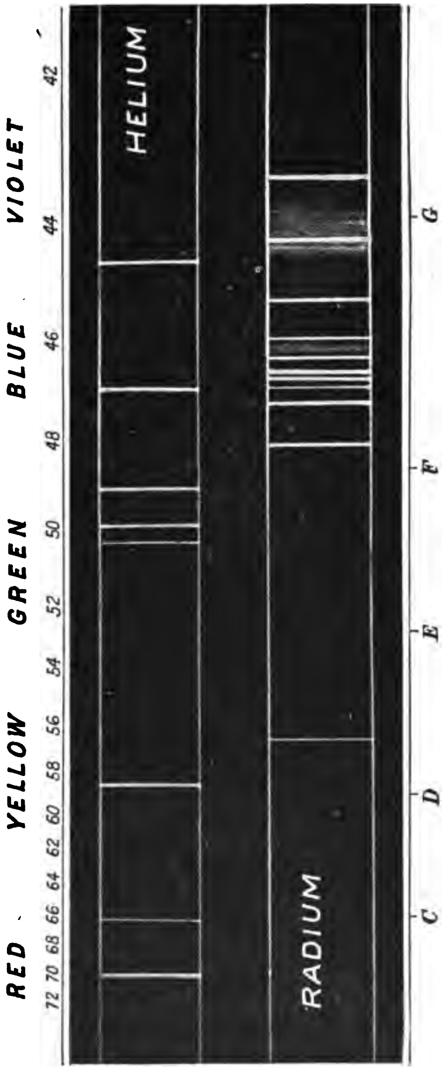

RED
YELLOW
GREEN
BLUE
VIOLET
72 70 68 66 64 62 60 58 56 54 52 50 48 46 44 42
HELIUM
RADIUM
C
D
E
F
G

Fig 10

FIG. 10.

A diagram of the *visible* lines of the spectrum of the elements Radium and Helium—when rendered incandescent by electric 'sparking' in a glass tube: kindly prepared for this book by Mr. Frederick Soddy of the University of Glasgow. The position of the chief great lines of the solar spectrum are marked on the lowest horizontal line. On the upper line the wave-lengths of the rays occupying the position indicated, are given. The figure 72 means that the wave-length of the ray occupying this position when refracted by the prism of the spectroscope is, as measured from crest to crest of the undulation, seven hundred and twenty millionths of a millimetre. . It is generally written 720·0 $\mu\mu$.

Lines exist at the ultra-violet end of the spectrum which can be photographed but do not affect the eye—that is to say are invisible. On the other hand the lines of the red end of the spectrum do not produce a photographic effect. Consequently a '*photographed*' spectrum such as that given in the next figure (fig. 11) differs in the lines presented both at the red and the violet ends from the *visible* series of lines. The two (visible and photographed spectra) agree only from wave-length 587·6 $\mu\mu$ to wave-length 447·2 $\mu\mu$.

The two spectra given in fig. 10 show how great is the difference in the position and number of the bands of Radium and Helium—yet as shown in the next figure (fig. 11) the 'emanation' from Radium actually is transformed into Helium.

enough for this observation; the lines given by radium are caused by no other known element in heaven or earth. They prove its title to be entered on the roll-call of elements.

The atomic weight was determined in the usual way by precipitating the chlorine in a solution of radium chloride by means of silver. None of the precious element was lost in the process, but the Curies never had enough of it to venture on any attempt to prepare pure metallic radium. This is a piece of extravagance no one has yet dared to undertake. Altogether the Curies did not have more than some four or five grains of chloride of radium to experiment with, and the total amount prepared and now in the hands of scientific men in various parts of the world probably does not amount to more than sixty grains at most. When Professor Curie lectured on radium four years ago at the Royal Institution in London he made use of a small tube an inch long and of one-eighth bore, containing nearly the whole of his precious store, wrenched by such determined labour and consummate skill from tons of black shapeless pitch-blende. On his return to Paris he was one day demonstrating in his lecture room with this precious tube the properties of radium when it slipped from his hands, broke, and scattered far and wide the most precious and magical powder ever dreamed of by alchemist or artist of romance. Every scrap of dust was immediately and carefully collected, dissolved, and re-crystallized, and the disaster averted with a loss of but a minute fraction of the invaluable product.

Thus, then, we have arrived at the discovery of radium—the new element endowed in an intense form with the new property 'radio-activity' discovered by Becquerel. The wonder of this powder, incessantly and

without loss, under any and all conditions pouring forth by virtue of its own intrinsic property powerful rays capable of penetrating opaque bodies and of exciting phosphorescence and acting on photographic plates, can perhaps be realized when we reflect that it is as marvellous as though we should dig up a stone which without external influence or change, continually poured forth light or heat, manufacturing both in itself, and not only continuing to do so without appreciable loss or change, but necessarily having always done so for countless ages whilst sunk beyond the ken of man in the bowels of the earth.

Wonderful as the story is, so far it is really simple and commonplace compared with what yet remains to be told. I will only barely and abruptly state the fact that radio-activity has been discovered in other elements, some very rare, such as actinium and polonium; others more abundant and already known, such as thorium and uranium, though their radio-activity was not known until Becquerel's pioneer-discovery. It is a little strange and no doubt significant that, after all, pure uranium is found to have a radio-activity of its own and not to have been altogether usurping the rights of its infinitesimal associate.

The wonders connected with radium really begin when the experimental examination of the properties of a few grains is made. What I am saying here is not a systematic, technical account of radium; so I shall venture to relate some of the story as it impresses me.

Leaving aside for a moment what has been done in regard to the more precise examination of the rays emitted by radium, the following astonishing facts have been found out in regard to it: (1) If a glass tube containing radium is much handled or kept in the waistcoat

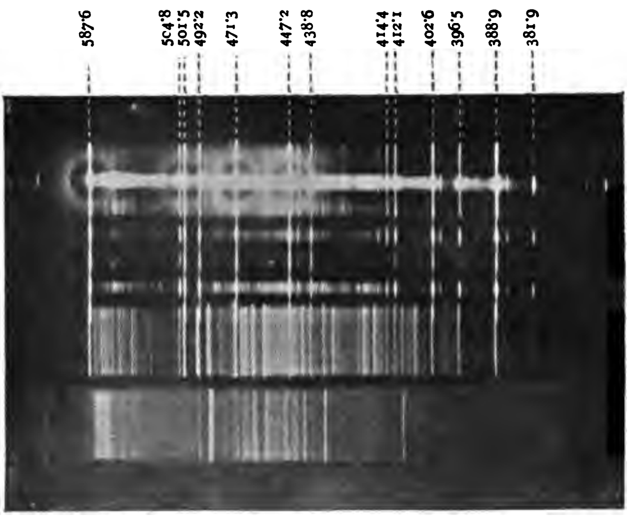
pocket, it produces a destruction of the skin and flesh over a small area—in fact, a sore place. (2) The smallest trace of radium brought into a room where a charged electroscope is present, causes the discharge of the electroscope. So powerful is this electrical action of radium that a very sensitive electrometer can detect the presence of a quantity of radium five hundred thousand times more minute than that which can be detected by the spectroscope (that is to say, by the spectroscopic examination of a flame in which minute traces of radium are present). (3) Radium actually realizes one of the properties of the hypothetical stone to which I compared it, giving out light and heat. For it does give out heat which it makes itself incessantly and without appreciable loss of substance or energy ('appreciable' is here an important qualifying term). It is also faintly self-luminous. Fairly sensitive thermometers show that a few granules of radium salt have always a higher temperature than that of surrounding bodies. Radium has been proved to give out enough heat to melt rather more than its own weight of ice every hour; enough heat in one hour to raise its own weight of water from the freezing-point to the boiling-point. After a year and six weeks a gram of radium has emitted enough heat to raise the temperature of a thousand kilograms of water one degree. And this is always going on. Even a small quantity of radium diffused through the earth will suffice to keep up its temperature against all loss by radiation! If the sun consists of a fraction of one per cent. of radium this will account for and make good the heat that is annually lost by it.

This is a tremendous fact, upsetting all the calculations of physicists as to the duration in past and future of the sun's heat and the temperature of the earth's

surface. The geologists and the biologists have long contended that some thousand million years must have passed during which the earth's surface has presented approximately the same conditions of temperature as at present, in order to allow time for the evolution of living things and the formation of the aqueous deposits of the earth's crust. The physicists, notably Professor Tait and Lord Kelvin, refused to allow more than ten million years (which they subsequently increased to a hundred million)—basing this estimate on the rate of cooling of a sphere of the size and composition of the earth. They have assumed that its material is self-cooling. But, as Huxley pointed out, mathematics will not give a true result when applied to erroneous data. It has now, within these last five years, become evident that the earth's material is *not* self-cooling, but on the contrary self-heating. And away go the restrictions imposed by physicists on geological time. They now are willing to give us not merely a thousand million years, but as many more as we want.

And now I have to mention the strangest of all the proceedings of radium—a proceeding in which the other radio-active bodies, actinium and thorium, resemble it. This proceeding has been entirely Rutherford's discovery in Canada, and his name must be always associated with it. Radium (he discovered) is continually giving off, apart from and in addition to the rectilinear darting rays of Becquerel—an 'emanation'—a gaseous 'emanation.' This 'emanation' is radio-active—that is, gives off Becquerel rays—and deposits 'something' upon bodies brought near the radium so that they become radio-active, and remain so for a time after the radium is itself removed. This emanation is always being formed by a radium salt, and may be most easily collected by

dissolving the salt in water, when it comes away with a rush, as a gas. Sixty milligrams of bromide of radium yielded to Ramsay and Soddy ·124 (or about one-eighth) of a cubic millimetre of this gaseous emanation. What is it? It cannot be destroyed or altered by heat or by chemical agents; it is a heavy gas, having a molecular density of 100, and it can be condensed to a liquid by exposing it to the great cold of liquid air. It gives a peculiar spectrum of its own, and is probably a hitherto unknown inert gas—a new element similar to argon. But this by no means completes its history, even so far as experiments have as yet gone. The radium emanation decays, changes its character altogether, and loses half its radio-activity every four days. Precisely at the same rate as it decays the specimen of radium salt from which it was removed forms a new quantity of emanation, having just the amount of radio-activity which has been lost by the old emanation. All is not known about the decay of the emanation, but one thing is absolutely certain, having first been discovered by Ramsay and Soddy and subsequently confirmed by independent experiment by Madame Curie. It is this: After being kept three or four days the emanation becomes, in part at least, converted into helium—the light gas (second only in the list of elements to hydrogen), the gas found twenty-five years ago by Lockyer in the sun, and since obtained in some quantities from rare radio-active minerals by Ramsay! The proof of the formation of helium from the radium emanation is, of course, obtained by the spectroscope, and its evidence is beyond assail (see fig. 11). Here, then, is the partial conversion or decay of one element, radium, through an intermediate stage into another. And not only that, but if, as seems probable, the presence of helium indicates the previous presence



A — Tube containing Helium gas derived from the mineral Clevelandite.

B — Tube of Radium emanation, a year old.

C — Tube of Hydrogen gas for comparison.

FIG. 11.

Photographs of the "spark' spectra of A, Helium as extracted from the mineral Clevelandite of B, the Radium "emanation" after a year's enclosure in the tube used and of C of Hydrogen gas: copied from the paper by Mr. F. Giesel in the *Berichte der Deutschen Chemischen Gesellschaft*, vol. xxxix, part 10.

The three photographs are accurately super-imposed so as to show the coincident lines.

The spectrum B of the tube containing radium emanation is the one which we are comparing with the other two. When the radium emanation was first enclosed there was only a small quantity of helium developed in it, but after keeping for a year the quantity has greatly increased. After five minutes "sparking" (passage of the electric spark through the tube) the chief lines of helium become evident but faint in intensity. The present photograph B was obtained after forty minutes sparking, and one result of that longer "sparking" has been that a minute quantity of water vapour in the tube has been broken up—*so as to yield the hydrogen spectrum*, which is accordingly seen accompanying the now strong and brightly developed helium spectrum.

The lines of the spectrum B which correspond with those of hydrogen are at once recognised by the juxtaposition (below) of the pure Hydrogen spectrum from another tube—C: the lines in B belonging to and indicating helium are also recognised by comparison with the pure helium spectrum of the tube A juxta-posed above. A very few of the lines in B must be due to other minimal impurities as they are not present either in A or C.

Thirteen lines of the helium spectrum are thus photographed and recognised in the radium emanation.

The following lines are present in the photographic but invisible spectrum of radium (not given in fig. 10), viz. at 381·47 $\mu\mu$ (the strongest line in the radium spectrum) and at 364·96 (a strong line).

In the photographic but invisible spectrum of helium there are three very faint lines between wave-length 447·2 and 443·7 (appearing as two only in our photograph); a moderately strong one at 438·8; others at 414·4, at 412·1, at 402·6, and 396·5; a very strong one is present at 388·9, and a very faint one at 381·9. All these are seen in the photograph A and also in B. Special treatment and spectroscopes reveal four other very faint lines in the helium spectrum—the one furthest in the invisible direction (that is of highest refrangibility and lowest wave-length) being placed at 3186 (Soddy).

of radium, we have the evidence of enormous quantities of radium in the sun, for we know helium is there in vast quantity. Not only that, but inasmuch as helium has been discovered in most hot springs and in various radio-active minerals in the earth, it may be legitimately argued that no inconsiderable quantity of radium is present in the earth. Indeed, it now seems probable that there is enough radium in the sun to keep up its continual output of heat, and enough in the earth to make good its loss of heat by radiation into space, for an almost indefinite period. Other experiments of a similar kind have rendered it practically certain that radium itself is formed by a somewhat similar transformation of uranium, so that our ideas as to the permanence and immutability on this globe of the chemical elements are destroyed, and must give place to new conceptions. It seems not improbable that the final product of the radium emanation after the helium is removed is or becomes the metal lead!

It must be obvious from all the foregoing that radium is very slowly, but none the less surely, destroying itself. There is a definite loss of particles which, in the course of time, must lead to the destruction of the radium, and it would seem that the large new credit on the bank of time given to biologists in consequence of its discovery has a definite, if remote, limit. With the quantities of radium at present available for experiment, the amount of loss of particles is so small, and the rate so slow, that it cannot be weighed by the most delicate balance. Nevertheless it has been calculated that radium will transform half of itself in about fifteen hundred years, and unless it were being produced in some way all of the radium now in existence would disappear much too soon to make it an important geological factor in the maintenance of the earth's temperature. As a reply to

this depreciatory statement we have the discovery by Rutherford and others that radium is continually being formed afresh, and from that particular element in connection with which it was discovered—namely, uranium. Hypotheses and experiments as to the details of this process are at this moment in full swing, and results of a momentous kind, involving the building-up of an element with high atomic weight by the interaction of elements with a lower atomic weight, are thought by some physicists to be not improbable in the immediate future.

The delicate electric test for radio-activity has been largely applied in the last few years to all sorts and conditions of matter. As a result it appears that the radium emanation is always present in our atmosphere; that the air in caves is especially rich in it, as are underground waters. Tin-foil, glass, silver, zinc, lead, copper, platinum and aluminium are, all of them, slightly radio-active. The question has been raised whether this widespread radio-activity is due to the wide dissemination of infinitesimal quantities of strong radio-active elements, or whether it is the natural intrinsic property of all matter to emit Becquerel rays. This is the immediate subject of research.

Over and above the more simply appreciable facts which I have thus narrated, there comes the necessary and difficult inquiry, What does it all mean? What *are* the Becquerel rays of radio-activity? What must we conceive to be the structure and mechanism of the atoms of radium and allied elements, which can not only pour forth ceaseless streams of intrinsic energy from their own isolated substance, but are perpetually, though in infinitesimal proportions, changing their elemental nature spontaneously, so as to give

rise to other atoms which we recognise as other elements?

I cannot venture as an expositor into this field. It belongs to that wonderful group of men, the modern physicists, who with an almost weird power of visual imagination combine the great instrument of exact statement and mental manipulation called mathematics, and possess an ingenuity and delicacy in appropriate experiment which must fill all who even partially follow their triumphant handling of Nature with reverence and admiration. Such men now or recently among us are Kelvin, Clerk Maxwell, Crookes, Rayleigh, and J. J. Thomson.

Becquerel showed early in his study of the rays emitted by radium that some of them could be bent out of their straight path by making them pass between the poles of a powerful electro-magnet. In this way have finally been distinguished three classes of rays given off by radium: (1) the *alpha* rays, which are only slightly bent, and have little penetrative power; (2) the *beta* rays, easily bent in a direction opposite to that in which the alpha rays bend, and of considerable penetrative power; (3) the *gamma* rays, which are absolutely unbendable by the strongest magnetic force, and have an extraordinary penetrative power, producing a photographic effect through a foot thickness of solid iron.

The *alpha* rays are shown to be streams of tiny bodies positively electrified, such as are given off by gas flames and red-hot metals. The particles have about twice the mass of a hydrogen atom, and they fly off with a velocity of 20,000 miles a second; that is, 40,000 times greater than that of a rifle bullet. The heat produced by radium is ascribed to the impact of these particles of the alpha rays.

The *beta* rays are streams of corpuscles similar to those given off by the cathode in a vacuum tube. They are charged with negative electricity and travel at the velocity of 100,000 miles a second. They are far more minute than the alpha particles. Their mass is equal to the one-thousandth of a hydrogen atom. They produce the major part of the photographic and phosphorescent effects of the radium rays.

The *gamma* rays are apparently the same, or nearly the same, thing as the X-rays of Röntgen. They are probably not particles at all, but pulses or waves in the ether set up during the ejection of the corpuscles which constitute the beta rays. They produce the same effects in a much smaller degree as do the beta rays, but are more penetrating.

The kind of conceptions to which these and like discoveries have led the modern physicist in regard to the character of that supposed unbreakable body—the chemical atom—the simple and unaffected friend of our youth—are truly astounding. Nevertheless, they are not destructive of our previous conceptions, but rather elaborations and developments of the simpler views, introducing the notion of structure and mechanism, agitated and whirling with tremendous force, into what we formerly conceived of as homogeneous or simply built-up particles, the earlier conception being not so much a positive assertion of simplicity as a non-committal expectant formula awaiting the progress of knowledge and the revelations which are now in our hands.

As I have already stated, the attempt to show in detail how the marvellous properties of radium and radio-activity in general are thus capable of a pictorial or structural representation is beyond the limits of the present essay; but the fact that such speculations

furnish a scheme into which the observed phenomena can be fitted is what we may take on the authority of the physicists and chemists of our day.

Intimately connected with all the work which has been done in the past twenty-five years in the nature and possible transformations of atoms is the great series of investigations and speculations on astral chemistry and the development of the chemical elements which we owe to the unremitting labour during this period of Sir Norman Lockyer.

Wireless telegraphy.—Of great importance has been the whole progress in the theory and practical handling of electrical phenomena of late years. The discovery of the Hertzian waves and their application to wireless telegraphy is a feature of this period, though I may remind some of those who have been impressed by these discoveries that the mere fact of electrical action at a distance is that which hundreds of years ago gave to electricity its name. The power which we have gained of making an instrument oscillate in accordance with a predetermined code of signalling, although detached and a thousand miles distant, does not really lend any new support[1] to the notion that the old-time beliefs of thought-transference and second sight are more than illusions based on incomplete observation and imperfect reasoning. For the important factors in such human intercourse—namely, a signalling-instrument and a code of signals—have not been discovered, as yet in the structure of the human body, and have to be consciously devised and manufactured by man in the only examples of thought-

[1] It seems necessary to emphasize that I here say merely that no "new support" is given to the notion of so-called telepathy, a support some persons have wrongly claimed. I do not say that the notion is rendered less likely to prove true than it was before.

transference over long distances at present discovered or laid bare to experiment and observation.

High and low temperatures.—The past quarter of a century has witnessed a great development and application of the methods of producing both very low and very high temperatures. Sir James Dewar, by improved apparatus, has produced liquid hydrogen and a fall of temperature probably reaching to the absolute zero. A number of applications of extremely low temperatures to research in various directions has been rendered possible by the facility with which they may now be produced. Similarly high temperatures have been employed in continuation of the earlier work of Deville, and others by Moissan, the distinguished French chemist.

Progress in Chemistry.—In chemistry generally the theoretical tendency guiding a great deal of work has been the completion and verification of the 'periodic law' of Mendeléeff; and, on the other hand, the search by physical agents such as light and electricity for evidence as to the arrangement of atoms in the molecules of the most diverse chemical compounds. The study of 'valency' and its outcome, stereo-chemistry, have been the special lines in which chemistry has advanced. As a matter of course hundreds, if not thousands, of new chemical bodies have been produced in the laboratory of greater or less theoretical interest. The discovery of the greatest practical and industrial importance in this connection is the production of indigo by synthetical processes, first by laboratory and then by factory methods, so as to compete successfully with the natural product. Von Baeyer and Heumann are the names associated with this remarkable achievement, which has necessarily dislocated a large industry which derived its raw material from British India.

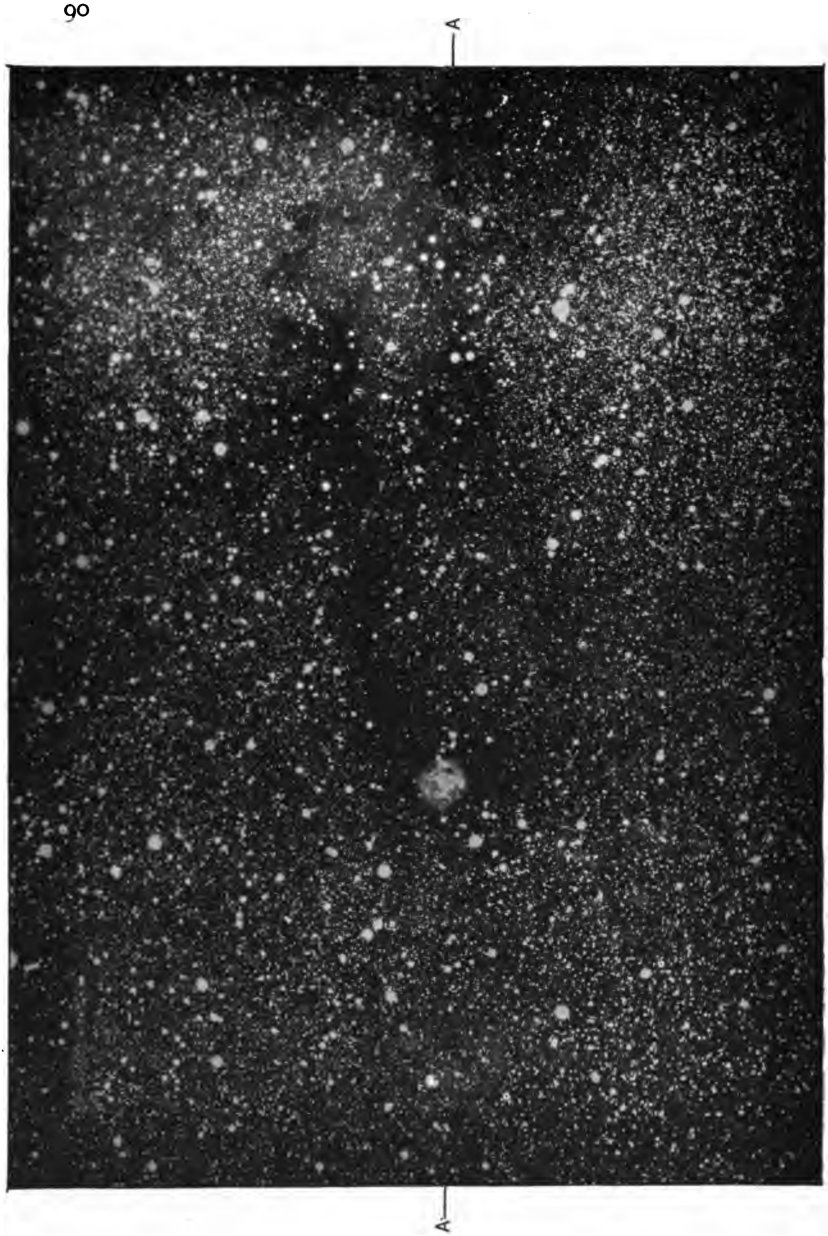


FIG. 12.

FIG. 12.

This figure should be examined with a magnifying glass. It is a direct reproduction of a photograph of a detached nebula and surrounding stars in Cygnus by Dr. Max Wolf of Heidelberg (reproduced by permission from the Monthly Notices of the Royal Astronomical Society, vol. lxiv, Plate 18, p. 839, q.v.). The exposure was four hours on July 10th, 1904, with a camera the lenses of which have a diameter of sixteen inches. The picture is enlarged so that the apparent diameter of the Sun or Moon would be about $1\frac{1}{3}$ inch on the same scale (one minute, or sixtieth of a degree, equals one millimetre).

The "apparent diameter" of the sun or moon is about one in 115: that is to say that a covering disc of any size you like can be made exactly to coincide with and "cover" the disc of the sun or moon provided that you place it at a distance from the eye equal to 115 times its own diameter—thus a disc of an inch in diameter (say a halfpenny) will just "cover" the sun or moon if placed at a distance from the eye of a little less than ten feet, a threepenny piece will cover it at about six feet, and a disc of somewhat less than half that size when held at arm's length.

The nebula (on the horizontal A A) is seen surrounded by a dark space—at the end of a long dark lane or "rift" which reminds us of the track left by a snowball rolled along in the snow. Has the nebula in some mysterious way swept up the stars in its journey through space? We cannot at present either affirm or deny such interpretations.

One or two of the brightest of the surrounding stars *might* just be seen by an acute eye unaided by a telescope—but no more. The best existing telescopes would show *only* the large nebular body on the line A A) and the larger white spots; the finest dust-like particles are stars of which the existence is only demonstrated by prolonged photographic exposures such as this, with a lens which focuses its image on to the *dry* plate. The old "wet-plate" would not remain wet sufficiently long to "take" the picture.

It should be borne in mind in looking at this picture that each of the minutest white spots is probably of at least the same size as our own sun: further, that each is probably surrounded by a planetary system similar to our own.

Astronomy.—A biologist may well refuse to offer any remarks on his own authority in regard to this earliest and grandest of all the sciences. I will therefore at once say that my friend the Savilian Professor of Astronomy in Oxford has turned my thoughts in the right direction in regard to this subject. There is no doubt that there has been an immense 'revival' in astronomy since 1881; it has developed in every direction. The invention of the 'dry plate,' which has made it possible to apply photography freely in all astronomical work, is the chief cause of its great expansion. Photography was applied to astronomical work before 1881, but only with difficulty and haltingly. It was the dry-plate (see Fig. 12) which made long exposures possible, and thus enabled astronomers to obtain regular records of faintly luminous objects such as nebulæ and star-spectra. Roughly speaking, the number of stars visible to the naked eye may be stated as eight thousand: this is raised by the use of our best telescopes to some hundred million. But the number which can be photographed is indefinite and depends on length of exposure: some thousands of millions can certainly be so recorded.

The serious practical proposal to 'chart the sky' by means of photography certainly dates from this side of 1881. The Paris Conference of 1887, which made an international scheme for sharing the sky among eighteen observatories (still busy with the work, and producing excellent results), originated with photographs of the comet of 1882, taken at the Cape Observatory.

Professor Pickering, of Harvard, did not join this co-operative scheme, but has gradually devised methods of charting the sky very rapidly, so that he has at Harvard records of the whole sky many times over, and when new objects are discovered he can trace their

history *backwards* for more than a dozen years by reference to his plates. This is a wonderful new method, a mode of keeping record of present movements and changes which promises much for the future of astronomy. By the photographic method hundreds of new variable stars and other interesting objects have been discovered. New planets have been detected by the hundred. Up to 1881 two hundred and twenty were known. In 1881 only one was found; namely, Stephania, being No. 220, discovered on May 19. Now a score at least are discovered every year. Over 500 are now known. One of these—Eros—(No. 433) is particularly interesting, since it is nearer to the sun than is Mars, and gives a splendid opportunity for fixing with increased accuracy the sun's distance from the earth. Two new satellites to Saturn and two to Jupiter have been discovered by photography (besides one to Jupiter in 1892 by the visual telescope of the Lick Observatory). One of the new satellites of Saturn goes round that planet the *wrong way*, thus calling for a fundamental revision of our ideas of the origin of the solar system.

The introduction of photography has made an immense difference in spectroscopic work. The spectra of the stars have been readily mapped out and classified, and now the motions in the line of sight of faint stars can be determined. This 'motion in the line of sight,' which was discernible but scarcely measurable with accuracy before, now provides one of the most refined methods in astronomy for ascertaining the dimensions and motions of the universe. It gives us velocities in miles per second instead of in an angular unit to be interpreted by a very imperfect knowledge of the star's distance. The method, initiated practically by Huggins thirteen years before, was in 1881 regarded by many

astronomers as a curiosity. Visual observations were begun at Greenwich in 1875, but were found to be affected by instrumental errors. The introduction of dry plates, and their application by Vogel in 1887, was the beginning of general use of the method, and line-of-sight work is now a vast department of astronomical industry. Among other by-products of the method are the 'spectroscopic doubles,' stars which we know to be double, and of which we can determine the period of revolution, though we cannot separate them visually by the greatest telescope.

Work on the sun has been entirely revolutionised by the use of photography. The last decade has seen the invention of the spectro-heliograph—which simply means that astronomers can now study *in detail* portions of the sun of which they could previously only get a bare indication.

More of the same story could be related, but enough has been said to show how full of life and progress is this most ancient and imposing of all sciences.

A minor though very important influence in the progress of astronomy has been the provision, by the expenditure of great wealth in America, of great telescopes and equipments.

In 1877 Sir George Darwin started a line of mathematical research which has been very fruitful and is of great future promise for astronomy. As recently as last April, at the Royal Astronomical Society, two important papers were read—one by Mr. Cowell and the other by Mr. Stratton—which have their roots in Sir George Darwin's work. The former was led to suggest that the day is lengthening ten times as rapidly as had been supposed, and the latter showed that in all probability the planets had all turned upside down since their birth.

And yet M. Brunettière and his friends wish us to believe that science is bankrupt and has no new things in store for humanity.

Geology.—In the field of geological research the main feature in the past twenty-five years has been the increasing acceptance of the evolutionary as contrasted with the uniformitarian view of geological phenomena. The great work of Suess, 'Das Antlitz der Erde,' is undoubtedly the most important contribution to physical geology within the period. The first volume appeared in 1885, and the impetus which it has given to the science may be judged of by the epithet applied to the views for which Suess is responsible—'the New Geology.' Suess attempts to trace the orderly sequence of the principal changes in the earth's crust since it first began to form. He strongly opposes the old theory of elevation, and accounts for the movements as due to differential collapse of the crust, accompanied by folding due to tangential stress. Among special results gained by geologists in the period we survey may be cited new views as to the origin of the crystalline schists, favouring a return to something like the hypogene origin advocated by Lyell; the facts as to deep-sea deposits, now in course of formation, embodied in the 'Challenger' reports on that subject: the increasing discrimination and tracking of those minor divisions of strata called 'zones'; the assignment of the Olenellus fauna of Cambrian age to a position earlier than that of the Paradoxides fauna; the discovery of Radiolaria in palæozoic rocks by special methods of examination, and the recognition of Graptolites as indices of geological horizons in lower palæozoic beds. Glacially eroded rocks in boulder-clays of permo-carboniferous age have been recognised in many parts of the world (*e.g.*, Australia and South Africa), and thus

the view put forward by W. T. Blanford as to the occurrence of the same phenomena in conglomerates of this age in India is confirmed. Eozoon is finally abandoned as owing its structure to an organism. The oldest fossiliferous beds known to us are still far from the beginning of life. They contain a highly developed and varied animal fauna—and something like the whole of the older moiety of rocks of aqueous origin have failed as yet to present us with any remains of the animals or plants which must have inhabited the seas which deposited them. The boring of a coral reef initiated by Professor Sollas at the Nottingham meeting of the British Association in 1893 was successfully carried out, and a depth of 1,114½ feet reached. Information of great value to geologists was thus obtained.

Animal and Vegetable Morphography.—Were I to attempt to give an account of the new kinds of animals and plants discovered since 1881, I should have to offer a bare catalogue, for space would not allow me to explain the interest attaching to each. Explorers have been busy in all parts of the world—in Central Africa, in the Antarctic, in remote parts of China, in Patagonia and Australia, and on the floor of the ocean as well as in caverns, on mountain tops, and in great lakes and rivers. We have learnt much that is new as to distribution; countless new forms have been discovered, and careful anatomical and microscopical study conducted on specimens sent home to our laboratories. I cannot refrain from calling to mind the discovery of the eggs of the Australian duck-mole and hedgehog; the fresh-water jelly-fish (figs. 13, 14, and 15) of Regent's Park, the African lakes (fig. 16) and the Delaware River; the marsupial mole of Central Australia; the okapi (figs. 17, 18, and 19); the breeding and transformations of the

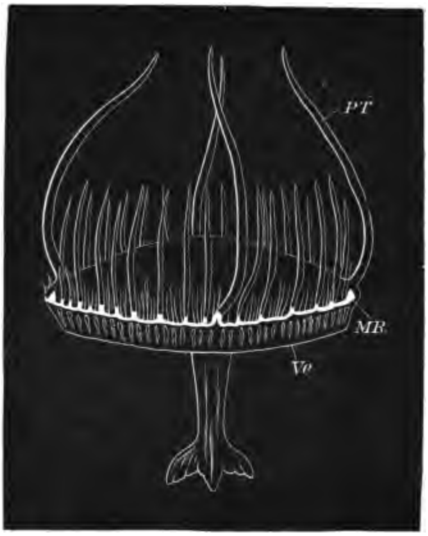


FIG. 13.

The Freshwater Jelly-fish of Regent's Park (*Limnocodium Sowerbii*) magnified five times linear.

It was discovered in the tropical lily tank of the Botanical Gardens in June, 1880, and swarmed in great numbers year after year—then suddenly disappeared. It has since been found in similar tanks in Sheffield, Lyons, and Munich. Only male specimens were discovered, and the native home of the wonderful visitor is still unknown.

FIG. 14.

The minute polyp attached to the rootlets of water-plants—from which the Jelly-fish *Limnocodium* was found to be 'budded off.'

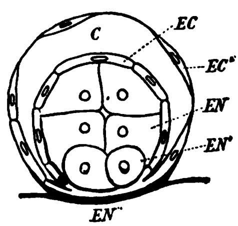


FIG. 15.

One of the peculiar sense-organs from the edge of the swimming disc of *Limnocodium*. C, cavity of capsule; EC, ectoderm; EN, endoderm. Sense-organs of identical structure are found in the Freshwater Jelly-fish of Lake Tanganyika and in no other jelly-fish.

common eel (fig. 20); the young and adult of the mud-fishes of Australia, Africa, and South America; the fishes of the Nile and Congo; the gill-bearing earth-worms and mud-worms; the various forms of the caterpillar-like *Peripatus;* strange deep-sea fishes, polyps and sponges.

The main result of a good deal of such investigation

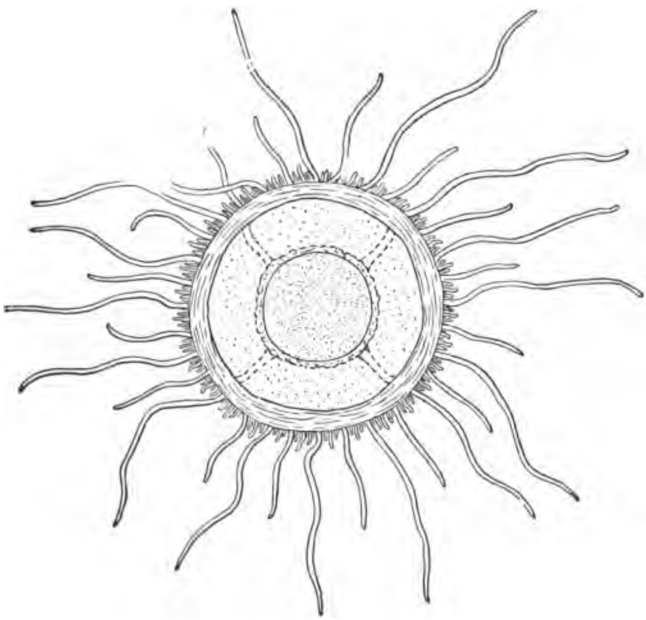


FIG. 16.

The Freshwater Jelly-fish of Lake Tanganyika (*Limnocodium Tanganyicae*), magnified five times linear. Since its discovery in Tanganyika it has been found also in the Lake Victoria Nyanza and in pools in the Upper Niger basin.

is measured by our increased knowledge of the pedigree of organisms, what used to be called 'classification.' The anatomical study by the Australian professors, Hill and Wilson, of the teeth and the fœtus of the Australian group of pouched mammals—the marsupials—has

FIG. 17.

The Giraffe-like animal called the Okapi, discovered by Sir Harry Johnston in the Congo Forest. Photograph of the skin of a female sent home by him in 1901, and now mounted and exhibited in the Natural History Museum.

FIG. 18.

Two "bandoliers" cut by the natives from the striped part of the skin (the haunches) and at first supposed to be bits of the hide of a new kind of Zebra. These were sent home by Sir Harry Johnston in 1900.

entirely upset previous notions, to the effect that these are a primitive group, and has shown that their possession of only one replacing tooth is a retention of one out of many such teeth (the germs of which are present), as in placental mammals; and further that many of these marsupials have the nourishing outgrowth of the fœtus called the placenta fairly well developed, so that

FIG. 19.

Photograph of the skull of a male Okapi—showing the paired boney horn-cores—similar to those of the Giraffe, but connected with the frontal bones and not with the parietals as the horn-cores of Giraffes are.

they must be regarded as a degenerate side-branch of the placental mammals, and not as primitive forerunners of that dominant series.

Speculations as to the ancestral connection of the great group of vertebrates with other great groups have been varied and ingenious; but most naturalists are now inclined to the view that it is a mistake to assume

any such connection in the case of vertebrates of a more definite character than we admit in the case of starfishes, shell-fish, and insects. All these groups are

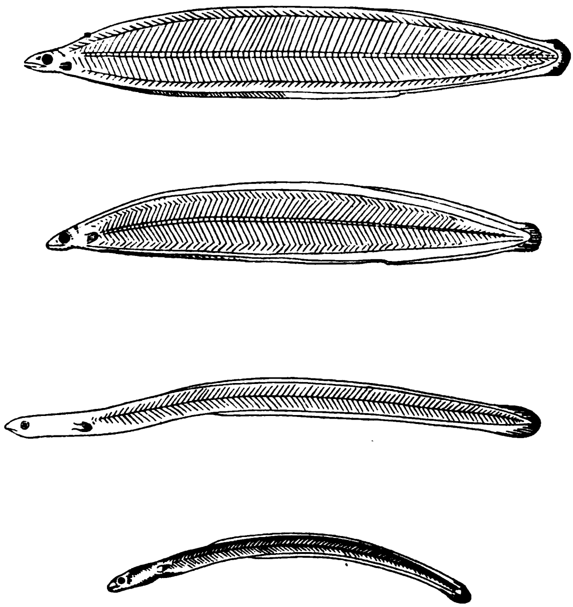


FIG. 20.

Drawings by Professor Grassi, of Rome, of the young of the common Eel and its metamorphosis. All of the natural size. The uppermost figure represents a transparent glass-like creature—which was known as a rare "find" to marine naturalists, and received the name *Leptocephalus*. Really it lives in vast numbers in great depths of the sea—five hundred fathoms and more. It is hatched here from the eggs of the common Eel which descends from the ponds, lakes, and rivers of Europe in order to breed in these great depths. The gradual change of the *Leptocephalus* into a young Eel or "Elver" is shown, and was discovered by Grassi. The young Eels leave the great depth of the ocean and ascend the rivers in immense shoals of many hundred thousand individuals, and wriggle their way up banks and rocks into the small streams and pools of the continent.

The above figures were published by Professor Grassi in November 1896, in the *Quarterly Journal of Microscopical Science*, edited by E. Ray Lankester and published by Churchill & Sons.

ultimately connected by very simple, remote, and not by proximate ancestors, with one another and with the ancestors of vertebrates.

The origin of the limbs of vertebrates is now generally agreed to be correctly indicated in the Thatcher-

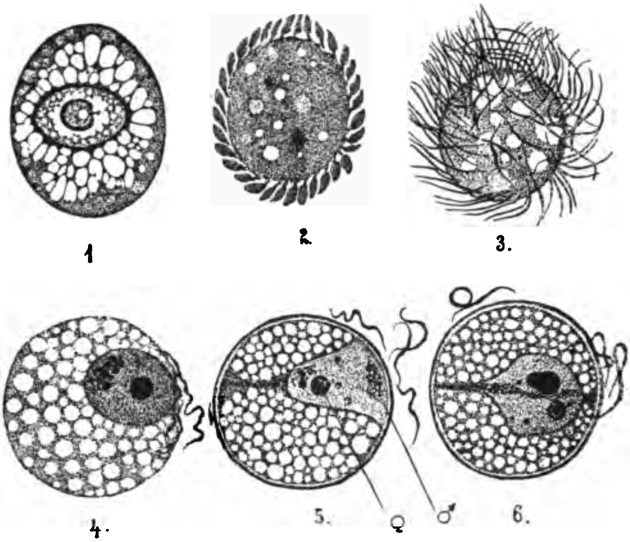


FIG. 21.

The unicellular parasite *Benedenia*, from the gut of the common Poulp or Octopus. 1, is the normal male individual; 2 and 3 show stages in the production of spermatozoa on its surface by budding; 4, 5 and 6 show a female parasite with spermatozoa approaching it:

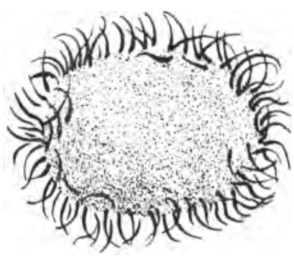


FIG. 22.

Production of spermatozoa on the surface of the unicellular parasite *Coccidium oviforme*, from the Rabbit's intestines.

Mivart-Balfour theory to the effect that they are derived from a pair of continuous lateral fins, in fish-like ancestors, similar in every way to the continuous median dorsal fin of fishes.

The discovery of the formation of true spermatozoa by simple unicellular animals of the group Protozoa is a startling thing, for it had always been supposed that these peculiar reproductive elements were only formed by multicellular organisms (figs. 21, 22, and 23). They

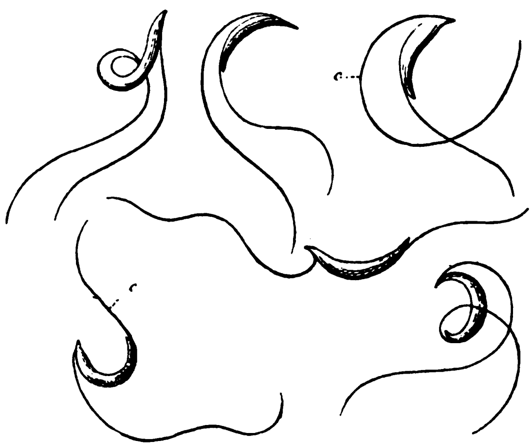


FIG. 23.

Spermatozoa (often called "microgametes") of the unicellular parasite *Echinospora* found in the gut of the small Centipede *Lithobius mutabilis*.

have been discovered in some of the gregarina-like animalcules, the *Coccidia*, and also in the blood-parasites.

Among plants one of the most important discoveries relates to these same reproductive elements, the spermatozoa, which by botanists are called antherozoids. A great difference between the whole higher series of plants, the flowering plants or phanerogams, and the

cryptogams or lower plants, including ferns, mosses, and algae, was held to be that the latter produce vibratile spermatozoa like those of animals which swim in liquid and fertilise the motionless egg-cell of the plant. Two Japanese botanists (and the origin of this discovery from Japan, from the University of Tokio, in itself marks an era in the history of science), Hirase and Ikeno, astonished the botanical world fifteen years ago by showing that motile antherozoids or spermatozoa are produced by two gymnosperms, the ging-ko tree (or *Salisburya*) and the cycads (fig. 24). The pollen-tube, which is the fertilising agent in all other phanerogams,

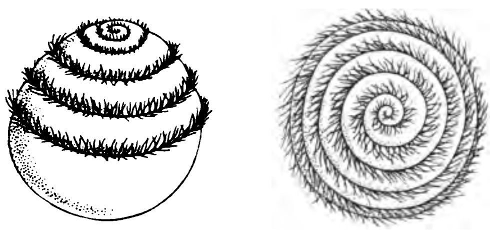


FIG. 24.

Spermatozoa (antherozoids) of *Cycas revoluta*, seen from the side and from above. The spermatozoon is spherical, carrying a spiral band of minute vibratile hairs (*cilia*) by which it is propelled.

develops in these cone-bearing trees, beautiful motile spermatozoa, which swim in a cup of liquid provided for them in connection with the ovules. Thus a great distinction between phanerogams and cryptogams was broken down, and the actual nature of the pollen-tube as a potential parent of spermatozoids demonstrated.

When we come to the results of the digging out and study of extinct plants and animals, the most remarkable results of all in regard to the affinities and pedigree of organisms have been obtained. Among plants the transition between cryptogams and phanero-

gams has been practically bridged over by the discovery that certain fern-like plants of the Coal Measures—the *Cycadofilices*, supposed to be true ferns, are really seed-bearing plants and not ferns at all, but phanerogams of a primitive type, allied to the cycads and gymnosperms. They have been re-christened *Pteridosperms* by Scott, who, together with F. Oliver and Seward, has been the chief discoverer in this most interesting field.

By their fossil remains whole series of new genera of extinct mammals have been traced through the tertiary strata of North America and their genetic connections established; and from yet older strata of the same prolific source we have almost complete knowledge of several genera of huge extinct *Dinosauria* of great variety of form and habit (fig. 25).

The discoveries by Seeley at the Cape, and by Amalitzky in North Russia of identical genera of Triassic reptiles, which in many respects resemble the Mammalia and constitute the group *Theromorpha*, is also a prominent feature in the palæontology of the past twenty-five years (fig. 26). Nor must we forget the extraordinary Devonian and Silurian fishes discovered and described by Professor Traquair (figs. 27 and 28). The most important discovery of the kind of late years has been that of the Upper Eocene and Miocene Mammals of the Egyptian Fayum, excavated by the Egyptian Geological Survey and by Dr. Andrews of the Natural History Museum, who has described and figured the remains. They include a huge four-horned animal as big as a rhinoceros, but quite peculiar in its characters—the *Arisinoïtherium*—and the ancestors of the elephants, a group which was abundant in Miocene and Pliocene times in Europe and Asia, and in still later times in America,

FIG. 25.

The gigantic three-horned Reptile, *Triceratops*, as large as an Elephant, found in Jurassic strata in North America. A model of the skeleton may be seen in the Natural History Museum in London.

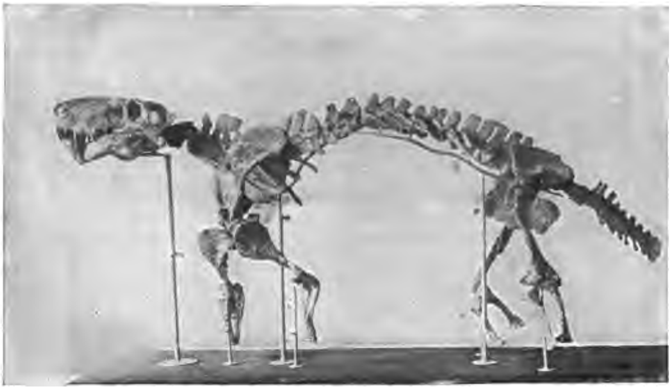


FIG. 26.

Photograph of the skeleton of a large carnivorous Reptile from Triassic strata in North Russia, discovered by Professor Amalitzky and named by him, *Inostransevia*. The head alone is two feet in length.

FIG. 27.

Photographs of completed models of the Devonian fish *Drepanaspis*, from Devonian slates of North Germany, worked out by Professor Traquair. The models are in the Natural History Museum, London.

and survives at the present day in its representatives the African and Indian elephant. One of the European extinct elephants—the *Tetrabelodon*—had, we have long known, an immensely long lower jaw with large chisel-shaped terminal teeth. It had been suggested by me that the modern elephant's trunk must have been derived from the soft upper jaw and nasal area, which rested on this elongated lower jaw, by the shortening (in the course of natural selection and modification by descent) of this long lower jaw, to the present small dimensions of the elephant's lower jaw, and the consequent down-dropping of the unshortened upper jaw and lips, which

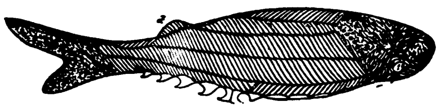


FIG. 28.

The oldest fossil fish known—discovered in the Upper Silurian strata of Scotland, and named *Birkenia* by Professor Traquair.

thus become the proboscis. Dr. Andrews has described from Egypt and placed in the Museum in London specimens of two new genera—one *Palæomastodon*, in which there is a long, powerful jaw, an elongated face, and an increased number of molar teeth (see figs. 29 and 30); the second, *Meritherium* (fig. 31), an animal with a hippopotamus-like head, comparatively minute tusks, and a well-developed complement of incisor, canine, and molar teeth, like a typical ungulate mammal. Undoubtedly we have in these two forms the indications of the steps by which the elephants have been evolved from ordinary-looking pig-like creatures of moderate size, devoid of trunk or tusks. Other remains belonging to this great mid-African Eocene fauna indicate that not

only the Elephants but the Sirenia (the Dugong and Manatee) took their origin in this area. Amongst them are also gigantic forms of Hyrax, like the little Syrian coney and many other new mammals and reptiles.

Another great area of exploration and source of new things has been the southern part of Argentina and

FIG. 29.

Photograph of a complete model of the skull and lower jaw of the ancestral elephant, *Palæomastodon*, discovered by Dr. Andrews in the Upper Eocene of the Fayum Desert, Egypt, and modelled and restored under his direction in the Natural History Museum, London The comparatively short trunk or snout rested on the broad front teeth of the long lower jaw. The face is elongated, and the cheek-teeth are numerous.

Patagonia, where Ameghino, Moreno, and Scott of Princeton have brought to light a wonderful series of

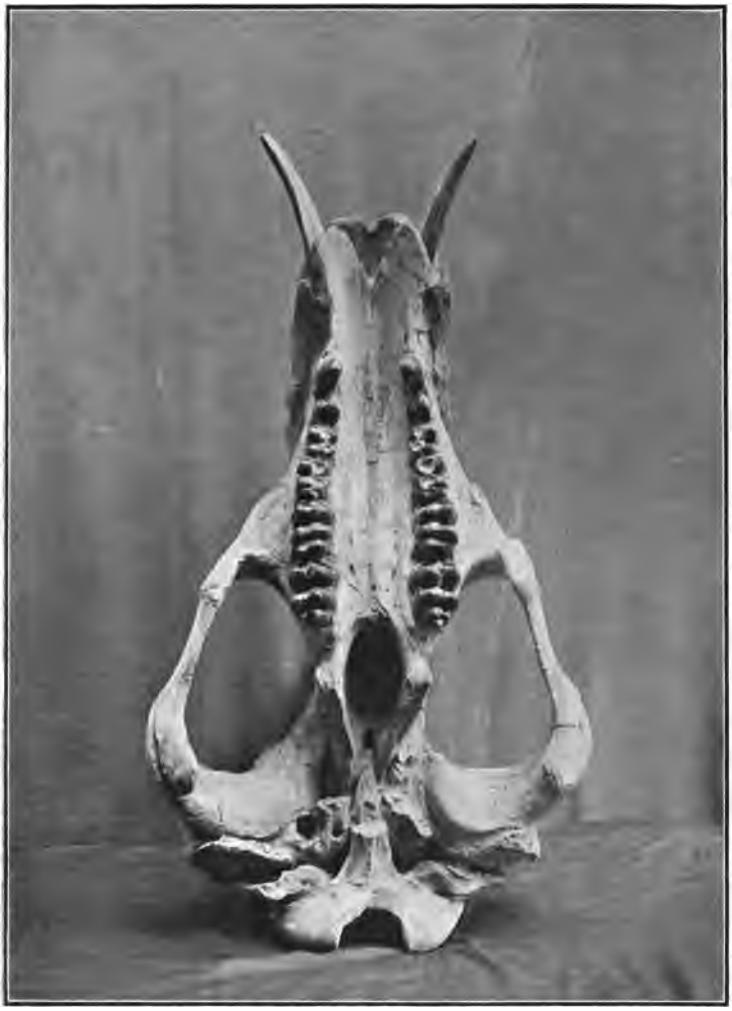


FIG. 30.

Photograph of the lower face of the skull of a specimen of *Palæomastodon* brought from Egypt in April, 1906, by Dr. Andrews, and now in the Natural History Museum, London. The six characteristic cheek-teeth on each side, and the pair of sabre-like tusks in front, are well seen.

extinct ant-eaters, armadilloes, huge sloths, and strange ungulates, reaching back into early Tertiary times. But most remarkable has been the discovery in this area of remains which indicate a former connection with the

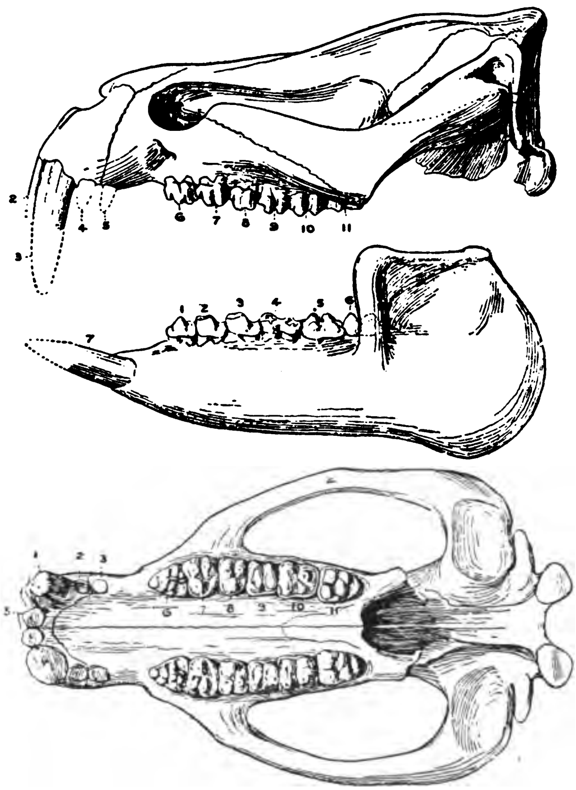


FIG. 31.

Drawing of the skull and lower jaw of the *Meritherium*, discovered by Dr. Andrews in the Upper Eocene of the Fayum Desert. The shape of the skull and proportions of face and jaw are like those of an ordinary hoofed mammal such as the pig; but the cheek-teeth are similar to those of the *Mastodon*, and whilst the full complement of teeth is present in the front of the upper jaw, we can distinguish the big tusk-like incisor which alone survives on each side in *Palæomastodon*, *Mastodon*, and the elephants, as the great pair of tusks.

Australian land surface. This connection is suggested by the discovery in the Santa Cruz strata, considered to be of early Tertiary date, of remains of a huge horned tortoise which is generically identical with one found fossil in the Australian area of later date, and known as *Miolania*. In the same wonderful area we have the discovery in a cave of the fresh bones, hairy skin, and dung of animals supposed to be extinct, viz., the giant sloth, *Mylodon*, and the peculiar horse, *Onohippidium*. These remains seem to belong to survivors from the last submergence of this strangely mobile land-surface, and it is not improbable that some individuals of this 'extinct' fauna are still living in Patagonia. The region is still unexplored and those who set out to examine it have, by some strange fatality, hitherto failed to carry out the professed purpose of their expeditions.

I cannot quit this immense field of gathered fact and growing generalisation without alluding to the study of animal embryology and the germ-layer theory, which has to some extent been superseded by the study of embryonic cell-lineage, so well pursued by some American microscopists. The great generalisation of the study of the germ-layers and their formation seems to be now firmly established—namely, that the earliest multicellular animals were possessed of one structural cavity, the enteron, surrounded by a double layer of cells, the ectoderm and endoderm. These *Enterocœla* or *Cœlentera* gave rise to forms having a second great body-cavity, the cœlom, which originated not as a split between the two layers, as was supposed twenty-five years ago by Haeckel and Gegenbaur and their pupils, but by a pouching of the enteron to form one or more cavities in which the reproductive cells should develop—pouchings which became nipped off from the cavity of their

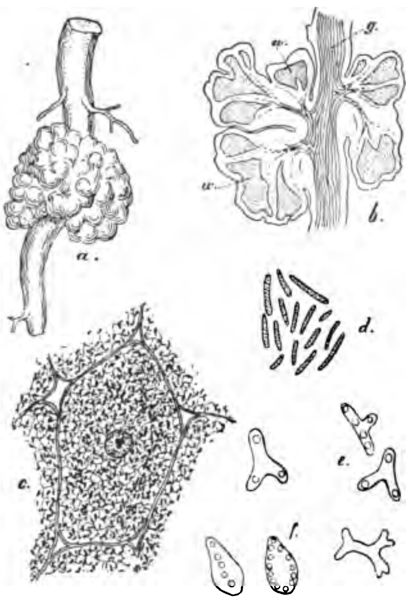
origin, and formed thus the independent cœlom. The animals so provided are the *Cœlomocœla* (as opposed to the *Enterocœla*), and comprise all animals above the polyps, jelly-fish, corals, and sea-anemones. It has been established in these twenty-five years that the cœlom is a definite structural unit of the higher groups, and that outgrowths from it to the exterior (cœlomoducts) form the genital passages, and may become renal excretory organs also. The vascular system has not, as it was formerly supposed to have, any connection of origin with the cœlom, but is independent of it, in origin and development, as also are the primitive and superficial renal tubes known as nephridia. These general statements seem to me to cover the most important advance in the general morphology of animals which we owe to embryological research in the past quarter of a century.[1]

Before leaving the subject of animal morphology I must apologise for my inability to give space and time to a consideration of the growing and important science of anthropology, which ranges from the history of human institutions and language to the earliest prehistoric bones and implements. Let me therefore note here the discovery of the cranial dome of *Pithecanthropus* in a river gravel in Java—undoubtedly the most ape-like of human remains, and of great age (see figs. 1 and 2); and, further, the Eoliths of Prestwich (see figs. 3 and 4), in the human authorship of which I am inclined to believe, though I should be sorry to say the same of all the broken flints to which the name 'Eolith' has been applied. The systematic investigation and record of savage races have taken on a new and scientific character. Such work as

[1] See the introduction to Part II. of a Treatise on Zoology. Edited by E. Ray Lankester (London: A. & C. Black).

Baldwin Spencer's and Haddon's in Australasia furnish examples of what is being done in this way.

Physiology of Plants and Animals.—Since I have not space to do more than pick out the most important advances in each subject for brief mention, I must signalize in regard to the physiology of plants the better understanding of the function of leaf-green or chlorophyll due



Bacillus radicola, the parasite which infests the roots of leguminous plants and causes the growth of nodules whilst assisting the plant in the assimilation of nitrogen: (*a*) Nodule of the roots of the common Lupine, natural size; (*b*) longitudinal section through a Lupine root and nodule; (*c*) a single cell from a Lupine nodule showing the bacteria or bacilli, as black particles in the protoplasm, magnified 600 diameters; (*d*) bacilli from the root nodule of the Lupine; (*e*) triangular forms of the bacillus from the root nodules of the Vetch; (*f*) oval forms from the root nodules of the Lupine; (*d e f*) are magnified 1,500 diameters.

FIG. 32.

to Pringsheim and to the Russian Timiriaseff, the new facts as to the activity of stomata in transpiration discovered by Horace Brown, and the fixation of free nitrogen by living organisms in the soil and by organisms (*Bacillus radicola*) parasitic in the rootlets of leguminous plants (see fig. 32), which thus benefit by a supply of nitrogenous compounds which they can assimilate.

Great progress in the knowledge of the chemistry of the living cells or protoplasm of both plants and animals has been made by the discovery of the fact that ferments or enzymes are not only secreted externally by cells, but exist active and preformed *inside* cells. Büchner's final conquest of the secret of the yeast-cell by heroic mechanical methods—the actual grinding to powder of these already very minute bodies—first established this, and now successive discoveries of intracellular ferments have led to the conclusion that it is probable that the cell respires by means of a respiratory 'oxydase,' builds up new compounds and destroys existing ones, contracts and accomplishes its own internal life by ferments. Life thus (from the chemical point of view) becomes a chain of ferment actions. Another most significant advance in animal physiology has been the sequel (as it were) of Bernard's discovery of the formation of glycogen in the liver, a substance not to be excreted, but to be taken up by the blood and lymph, and in many ways more important than the more obvious formation of bile which is thrown out of the gland into the alimentary canal. It has been discovered that many glands, such as the kidney and pancreas and the ductless glands, the supra-renals, thyroid, and others, secrete indispensable products into the blood and lymph. Hence myxœdema, exophthalmic goitre, Addison's disease, and other disorders have been traced to a deficiency or excess of internal secretions from glands formerly regarded as interesting but unimportant vestigial structures. From these glands have in consequence been extracted remarkable substances on which their peculiar activity depends. From the suprarenals a substance has been extracted which causes activity of all those structures which the sympathetic nerve-system can excite to action:

the thyroid yields a substance which influences the growth of the skin, hair, bones, &c.; the pituitary gland, an extract which is a specific urinary stimulant. Quite lately the mammalian ovary has been shown by Starling to yield a secretion which influences the state of nutrition of the uterus and mammæ. A great deal more might be said here on topics such as these—topics of almost infinite importance; but the fact is that the mere enumeration of the most important lines of progress in any one science would occupy many pages.

Nerve-physiology has made immensely important advances. There is now good evidence that all excitation of one group of nerve-centres is accompanied by the *concurrent inhibition* of a whole series of groups of other centres, whose activity might interfere with that of the group excited to action. In a simple reflex flexure of the knee the motor-neurones to the flexor muscles are excited, but concurrently the motor-neurones to the extensor muscles are thrown into a state of inhibition, and so equally with all the varied excitations of the nervous system controlling the movements and activities of the entire body.

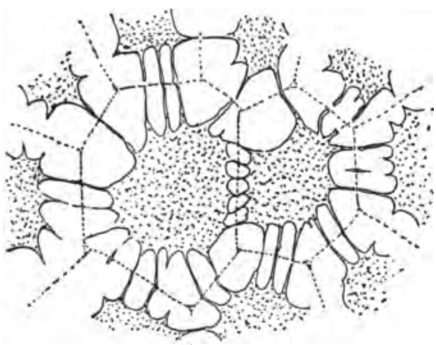


FIG. 33.

The continuity of the protoplasm of neighbouring vegetable cells, by means of threads which perforate the cell-walls. Drawing (*after* Gardiner) of cells from the pulvinus of *Robinia*.

The discovery of the continuity of the protoplasm through the walls of the vegetable cells by means of con-

necting canals and threads (see fig. 33) is one of the most startling facts discovered in connection with plant-structure, since it was held twenty years ago that a fundamental distinction between animal and vegetable structure consisted in the boxing-up or encasement of each vegetable cell-unit in a case of cellulose, whereas animal cells were not so imprisoned, but freely communicated with one another. It perhaps is on this account the less sur-

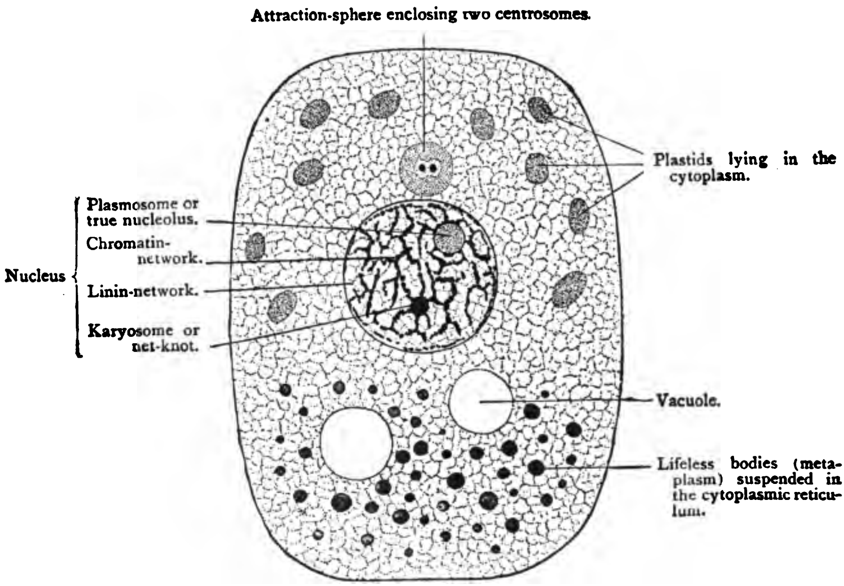


FIG. 34.

Diagrammatic representation of the structures present in a typical cell (*after* Wilson). Note the two centrosomes, sometimes single.

prising that lately something like sense-organs have been discovered on the roots, stems, and leaves of plants, which, like the otocysts of some animals, appear to be really 'statocytes,' and to exert a varying pressure according to the relations of these parts of the plant to gravity. There is apparently something resembling a perception of the

incidence of gravity in plants which reacts on irritable tissues, and is the explanation of the phenomena of geotropism. These results have grown out of the observations of Charles Darwin, followed by those of F. Darwin, Haberlandt, and Nemec.

A few words must be said here as to the progress of our knowledge of cell-substance, and what used to be called the protoplasm question. We do not now regard protoplasm as a chemical expression, but, in accordance with von Mohl's original use of the word, as a structure which holds in its meshes many and very varied chemical bodies of great complexity. Within these twenty-five years the 'centrosome' of the cell-protoplasm has been discovered (see fig. 34), and a great deal has been learnt as to the structure of the nucleus and its remarkable stain-taking bands, the chromosomes. We now know that these bands are of definite fixed number, varying in different species of plants and animals, and that they are halved in number in the reproductive elements—the spermatozoid and the ovum—so that on union of these two to form the fertilized ovum (the parent cell of all the tissues), the proper specific number is attained (see figs. 35 and 36). It has been pretty clearly made out by cutting up large living cells—unicellular animals—that the body of the cell alone, without the nucleus, can do very little but move and maintain for a time its chemical status. But it is the nucleus which directs and determines all definite growth, movement, secretion, and reproduction. The simple protoplasm, deprived of its nucleus, cannot form a new nucleus—in fact, can do very little but exhibit irritability. I am inclined to agree with those who hold that there is not sufficient evidence that any organism exists at the present time which has not both protoplasm and nucleus

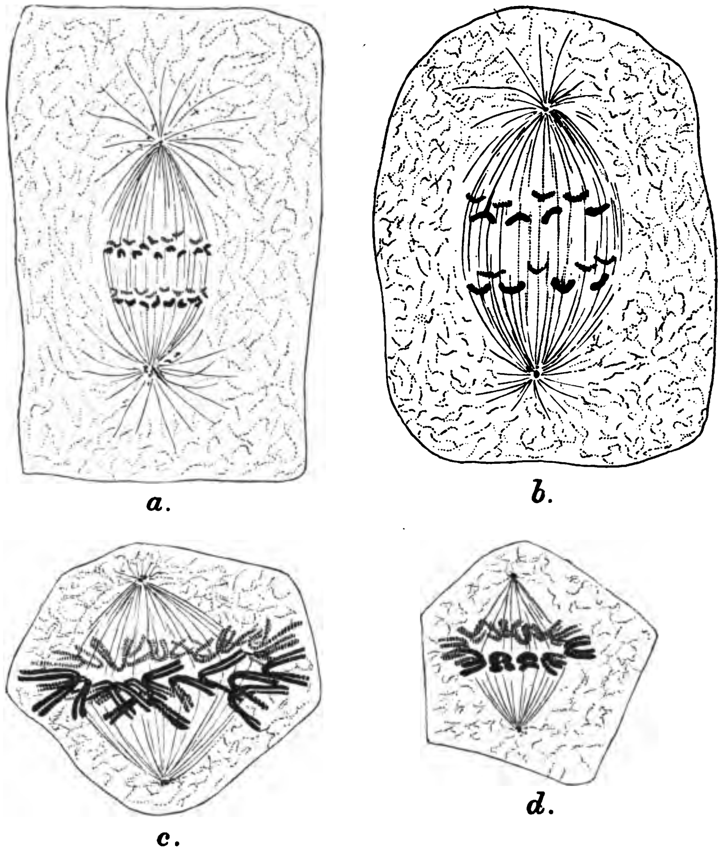


Fig. 35.—The Number of the Chromosomes: (*a*) Cell of the asexual generation of the cryptogam *Pellia epiphylla*: the nucleus is about to divide, a polar ray-formation is present at each end of the spindle-shaped nucleus, the chromosomes have divided into two horizontal groups each of sixteen pieces: *sixteen* is the number of the chromosomes of the ordinary tissue cells of *Pellia*. (*b*) Cell of the sexual generation of the same plant (*Pellia*) in the same phase of division, but with the *reduced* number of chromosomes —namely, *eight* in each half of the dividing nucleus. The completed cells of the sexual generation have only *eight* chromosomes. (*c*) Somatic or tissue cell of Salamander showing *twenty-four* V-shaped chromosomes, each of which is becoming longitudinally split as a preliminary to division. (*d*) Sperm-mother-cell from testis of Salamander, showing the *reduced* number of chromosomes of the sexual cells—namely, *twelve*; each is split longitudinally. (From original drawings by Prof. Farmer and Mr. Moore.)

—in fact, that the simplest form of life at present existing is a highly complicated structure—a nucleated cell. That does not imply that simpler forms of living matter have not preceded those which we know. We must assume that something more simple and homogeneous than the cell, with its differentiated cell-body or protoplasm, and its cell kernel or nucleus, has at one time existed. But the various supposed instances of the survival to the present day of such simple living things—described by Haeckel and others—have one by one yielded to improved methods of microscopic examination and proved to be differentiated into nuclear and extra-nuclear substance.

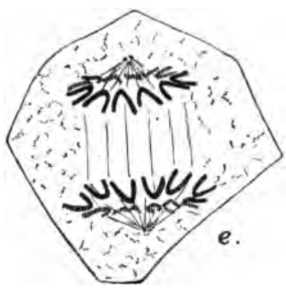


FIG. 36.

Further stage in the division of the sexual cell drawn in Fig. 35 (*e*), showing the *twelve* chromosomes of the two nuclei of the sperm-cells resulting from the division (*twelve* instead of *twenty-four*).

The question of 'spontaneous generation' cannot be said to have been seriously revived within these twenty-five years. Our greater knowledge of minute forms of life, and the conditions under which they can survive, as well as our improved microscopes and methods of experiment and observation, have made an end of the arguments and instances of supposed abiogenesis. The accounts which have been published of 'radiobes,' minute bodies arising in fluids of organic origin when radium salts have been allowed to mix in minute quantities with such fluids, are wanting in precision and detail, but the microscopic particles which appear in the circumstances described seem to be of a nature identical with the minute bodies well known to microscopists and recognised as

crystals modified by a colloid medium. They have been described by Rainey, Harting, and Ord, on different occasions, many years ago. They are not devoid of interest, but cannot be considered as having any new bearing on the origin of living matter.

Psychology.—I have given a special heading to this subject because its emergence as a definite line of experimental research seems to me one of the most important features in the progress of science in the past quarter of a century. Thirty-five years ago we were all delighted by Fechner's psycho-physical law, and at Leipzig I, with others of my day, studied it experimentally in the physiological laboratory of that great teacher, Carl Ludwig. The physiological methods of measurement (which are the physical ones) have been more and more widely, and with guiding intelligence and ingenuity, applied since those days to the study of the activities of the complex organs of the nervous system which are concerned with 'mind' or psychic phenomena. Whilst some enthusiasts have been eagerly collecting ghost stories and records of human illusion and fancy, the serious experimental investigation of the human mind, and its forerunner the animal mind, has been quietly but steadily proceeding in truly scientific channels. The science is still in an early phase—that of the collection of accurate observations and measurements—awaiting the development of great guiding hypotheses and theories. But much has been done, and it is a matter of gratification to Oxford men that through the liberality of the distinguished electrician, Mr. Henry Wilde, F.R.S., a lectureship of Experimental Psychology has been founded in the University of Oxford, where the older studies of Mental and Moral Philosophy, Logic and Metaphysics have so strong a hold, and have so well prepared the ground for the new experimental

development. The German investigators W. Wundt, G. E. Müller, C. Stumpf, Ebbinghaus, and Munsterberg have been prominent in introducing laboratory methods, and have determined such matters as the elementary laws of association and memory, and the perceptions of musical tones and their relations. The work of Goldschneider on 'the muscular sense,' of von Frey on the cutaneous sensations, are further examples of what is being done.

The difficult and extremely important line of investigation, first scientifically treated by Braid under the name 'Hypnotism,' has been greatly developed by the French school, especially by Charcot. The experimental investigation of 'suggestion,' and the pathology of dual consciousness and such exceptional conditions of the mind, has been greatly advanced by French observers.

The older work of Ferrier and Hitzig on the functions of the parts of the brain has been carried further by Goltz and Munk in Germany, and by Schäfer, Horsley, and Sherrington in England.

The most important general advance seems to be the recognition that the mind of the human adult is a social product; that it can only be understood in relation with the special environment in which it develops, and with which it is in perpetual interaction. Professor Baldwin, of Princeton, has done important work on this subject. Closely allied is the study of what is called 'the psychology of groups,' the laws of mental action of the individual as modified by his membership of some form of society. French authors have done valuable work here.

These two developments of psychology are destined to provide the indispensable psychological basis for Social Science, and for the anthropological investigation of mental phenomena.

Hereafter, the well-ascertained laws of experimental psychology will undoubtedly furnish the necessary scientific basis of the art of education, and psychology will hold the same relation to that art as physiology does to the art of medicine and hygiene.

There can be little doubt, moreover, of the valuable interaction of the study of physical psychology and the theories of the origin of structural character by natural selection. The relation of the human mind to the mind of animals, and the gradual development of both, form a subject full of rich stores of new material, yielding conclusions of the highest importance, which has not yet been satisfactorily approached.

I am glad to be able to give wider publicity here to some conclusions which I communicated to the Jubilee volume of the 'Société de Biologie' of Paris in 1899. I there discussed the significance of the great increase in the size of the cerebral hemispheres in recent, as compared with Eocene Mammals (see fig. 5), and in Man as compared with Apes, and came to the conclusion that 'the power of building up appropriate cerebral mechanism in response to individual experience,' or what may be called 'educability,' is the quality which characterizes the larger cerebrum, and is that which has led to its selection, survival, and further increase in volume. The bearing of this conception upon questions of fundamental importance in what has been called genetic psychology is sketched as follows:

'The character which we describe as "educability" can be transmitted; it is a congenital character. But the *results* of education can *not* be transmitted. In each generation they have to be acquired afresh. With increased "educability" they are more readily acquired and a larger variety of them. On the other hand, the

nerve-mechanisms of instinct are transmitted, and owe their inferiority as compared with the results of education to the very fact that they are *not* acquired by the individual in relation to his particular needs, but have arisen by selection of congenital variation in a long series of preceding generations.'

'To a large extent the two series of brain-mechanisms, the "instinctive" and the "individually acquired," are in opposition to one another. Congenital brain-mechanisms may prevent the education of the brain and the development of new mechanisms specially fitted to the special conditions of life. To the educable animal the less there is of specialised mechanism transmitted by heredity, the better. The loss of instinct is what permits and necessitates the education of the receptive brain.'

'We are thus led to the view that it is hardly possible for a theory to be further from the truth than that expressed by George H. Lewes and adopted by George Romanes, namely, that instincts are due to "lapsed" intelligence. The fact is that there is no community between the mechanisms of instinct and the mechanisms of intelligence, and that the latter are later in the history of the development of the brain than the former, and can only develop in proportion as the former become feeble and defective.'[1]

Darwinism.—Under the title 'Darwinism' it is convenient to designate the various work of biologists tending to establish, develop, or modify Mr. Darwin's great theory of the origin of species. In looking back over twenty-five years it seems to me that we must say that the conclusions of Darwin as to the origin of

[1] From the Jubilee volume of the Soc. de Biol. of Paris, 1899. Reprinted in *Nature*, vol. lxi., 1900, pp. 624, 625.

species by the survival of selected races in the struggle for existence are more firmly established than ever. And this because there have been many attempts to gravely tamper with essential parts of the fabric as he left it, and even to substitute conceptions for those which he endeavoured to establish, at variance with his conclusions. These attempts must, I think, be considered as having failed. A great deal of valuable work has been done in consequence; for honest criticism, based on observation and experiment, leads to further investigation, and is the legitimate and natural mode of increase of scientific knowledge. Amongst the attempts to seriously modify Darwin's doctrine may be cited that to assign a great and leading importance to Lamarck's theory as to the transmission by inheritance of newly 'acquired' characters, due chiefly to American palæontologists and to the venerated defender of such views, who has now closed his long life of great work, Mr. Herbert Spencer; that to attribute leading importance to the action of physiological congruity and incongruity in selective breeding, which was put forward by another able writer and naturalist who has now passed from among us, Dr. George Romanes; further, the views of de Vries as to the discontinuity in the origin of new species, supported by the valuable work of Mr. Bateson on discontinuous variation; and lastly, the attempt to assign a great and general importance to the facts ascertained many years ago by the Abbé Mendel as to the cross-breeding of varieties and the frequent production (in regard to certain characters in certain cases) of pure strains rather than of breeds combining the characters of both parents. On the other hand we have the splendid series of observations and writings of August Weismann, who has, in the opinion of the

majority of those who study this subject, rendered the Lamarckian theory of the origin and transmission of new characters altogether untenable, and has, besides, furnished a most instructive, if not finally conclusive, theory or mechanical scheme of the phenomena of Heredity in his book 'The Germ-plasm.' Professor Karl Pearson and the late Professor Weldon—the latter so early in life and so recently lost to us—have, with the finest courage and enthusiasm in the face of an enormous and difficult task, determined to bring the facts of variation and heredity into the solid form of statistical statement, and have organised, and largely advanced in, this branch of investigation which they have termed 'Biometrics.' Many naturalists throughout the world have made it the main object of their collecting and breeding of insects, birds, and plants, to test Darwin's generalisations and to expand the work of Wallace in the same direction. A delightful fact in this survey is that we find Mr. Alfred Russel Wallace (who fifty years ago conceived the same theory as that more fully stated by Darwin) actively working and publishing some of the most convincing and valuable works on Darwinism. He is still alive and not merely well, but pursuing his work with vigour and ability. It was chiefly through his researches on insects in South America and the Malay Islands that Mr. Wallace was led to the Darwinian theory; and there is no doubt that the study of insects, especially of butterflies, is still one of the most prolific fields in which new facts can be gathered in support of Darwin and new views on the subject tested. Prominent amongst naturalists in this line of research has been and is Edward Poulton of Oxford, who has handed on to the study of entomology throughout the world the impetus

of the Darwinian theory. I must here also name a writer who, though unknown in our laboratories and museums, seems to me to have rendered very valuable service in later years to the testing of Darwin's doctrines and to the bringing of a great class of organic phenomena within the cognisance of those naturalists who are especially occupied with the problems of Variation and Heredity. I mean Dr. Archdall Reid, who has with keen logic made use of the immense accumulation of material which is in the hands of medical men, and has pointed out the urgent importance of increased use by Darwinian investigators of the facts as to the variation and heredity of that unique animal, man, unique in his abundance, his reproductive activity, and his power of assisting his investigator by his own record. There are more observations about the variation and heredity of man and the conditions attendant upon individual instances than with regard to any other animal. Medical men need only to grasp clearly the questions at present under discussion in order to be able to furnish with ease data absolutely invaluable in quantity and quality. Dr. Archdall Reid has in two original books full of insight and new suggestions, the 'Present Evolution of Man' and 'Principles of Heredity,' shown a new path for investigators to follow.

The attempt to resuscitate Lamarck's views on the inheritance of acquired[1] characters has been met not only by the demand for the production of experimental

[1] I use the term 'acquired' without prejudice in the sense given to that word by Lamarck himself. It is of primary importance that those who follow this controversy should clearly understand what Lamarck pointed to by this word 'acquired.' Utter confusion and absurdity has resulted from a misunderstanding on this subject by some writers who deliberately call newly appearing congenital characters 'acquired' or 'acquisitions.'

proof that such inheritance takes place, which has never been produced, but on Weismann's part by a demonstration that the reproductive cells of organisms are developed and set aside from the rest of the tissues at so early a period that it is extremely improbable that changes brought about in those other tissues by unaccustomed incident forces can be communicated to the germ-cells so as to make their appearance in the offspring by heredity. Apart from this, I have drawn attention to the fact that Lamarck's first and second laws (as he terms them) of heredity are contradictory the one of the other, and therefore may be dismissed. In 1894 I wrote:

'Normal conditions of environment have for many thousands of generations moulded the individuals of a given species of organism, and determined as each individual developed and grew "responsive" quantities in its parts (characters); yet, as Lamarck tells us, and as we know, there is in every individual born a potentiality which has *not* been extinguished. Change the normal conditions of the species in the case of a young individual taken to-day from the site where for thousands of generations its ancestors have responded in a perfectly defined way to the normal and defined conditions of environment; reduce the daily or the seasonal amount of solar radiation to which the individual is exposed; or remove the aqueous vapour from the atmosphere; or alter the chemical composition of the pabulum accessible; or force the individual to previously unaccustomed muscular effort or to new pressures and strains; and (as Lamarck bids us observe), in spite of all the long-continued response to the earlier normal specific conditions, the innate congenital potentiality shows itself. The individual under the new quantities of environing

agencies shows *new* responsive quantities in those parts of its structure concerned, new or *acquired* characters.

'So far, so good. What Lamarck next asks us to accept, as his "second law," seems not only to lack the support of experimental proof, but to be inconsistent with what has just preceded it. The new character which is *ex hypothesi*, as was the old character (length, breadth, weight of a part) which it has replaced—a response to environment, a particular moulding or manipulation by incident forces of the potential congenital quality of the race—is, according to Lamarck, all of a sudden raised to extraordinary powers. The new or freshly acquired character is declared by Lamarck and his adherents to be capable of transmission by generation; that is to say, it alters the potential character of the species. It is no longer a merely responsive or reactive character, determined quantitatively by quantitative conditions of the environment, but becomes fixed and incorporated in the potential of the race, so as to persist when other quantitative external conditions are substituted for those which originally determined it. In opposition to Lamarck, one must urge, in the first place, that this thing has never been shown experimentally to occur; and in the second place, that there is no ground for holding its occurrence to be probable, but, on the contrary, strong reason for holding it to be improbable. Since the old character (length, breadth, weight) had not become fixed and congenital after many thousands of successive generations of individuals had developed it in response to environment, but gave place to a new character when new conditions operated on an individual (Lamarck's first law), why should we suppose that the new character is likely to become fixed after a much shorter time of responsive existence, or to escape the

K

operation of the first law? Clearly there is no reason (so far as Lamarck's statement goes) for any such supposition, and the two so-called laws of Lamarck are at variance with one another.'

In its most condensed form my argument has been stated thus by Professor Poulton: Lamarck's 'first law assumes that a past history of indefinite duration is powerless to create a bias by which the present can be controlled; while the second assumes that the brief history of the present can readily raise a bias to control the future.'[1]

An important light is thrown on some facts which seem at first sight to favour the Lamarckian hypothesis by the consideration that, though an 'acquired' character is not transmitted to offspring as the consequence of the action of external agencies determining the 'acquirement,' yet the tendency to react exhibited by the parent *is* transmitted, and if the tendency is exceptionally great a false suggestion of a Lamarckian inheritance can readily result. This inheritance of 'variation in tendencies to react' has a wide application, and has led me to coin the word 'educability' as mentioned in the section of this address on Psychology.

The principle of physiological selection advocated by Dr. Romanes does not seem to have caused much discussion, and has been unduly neglected by subsequent writers. It was ingenious, and was based on some interesting observations, but has failed to gain support.

The observations of de Vries—showing that in cultivated varieties of plants a new form will sometimes assert itself suddenly and attain a certain period of dominance, though not having been gradually brought

[1] *Nature*, vol. li., 1894, p. 127.

into existence by a slow process of selection—have been considered by him, and by a good many other naturalists, as indicating the way in which new species arise in Nature. The suggestion is a valuable one if not very novel, but a great deal of observation will have to be made before it can be admitted as really having a wide bearing upon the origin of species. The same is true of those interesting observations which were first made by Mendel, and have been resuscitated and extended with great labour and ingenuity by recent workers, especially in this country by Bateson and his pupils. If it should prove to be true that varieties when crossed do not, in the course of eventual inter-breeding, produce intermediate forms as hybrids, but that characters are either dominant or recessive, and that breeds result having pure unmixed characters—we should, in proportion as the Mendelian law is shown to apply to all tissues and organs and to a majority of organisms, have before us a very important and determining principle in all that relates to heredity and variation. It remains, however, to be shown how far the Mendelian phenomenon is general. And it is, of course, admitted on all sides that, even were the Mendelian phenomenon general and raised to the rank of a law of heredity, it would not be subversive of Mr. Darwin's generalisations, but probably tend to the more ready application of them to the explanation of many difficult cases of the structure and distribution of organisms.

Two general principles which Mr. Darwin fully recognised appear to me to deserve more consideration and more general application to the history of species than he had time to give to them, or than his followers have accorded to them. The first is the great principle of 'correlation of variation,' from which it follows that,

whilst natural selection may be favouring some small and obscure change in an unseen group of cells—such as digestive, pigmentary or nervous cells, and that change a change of selective value—there may be, indeed often is, as we know, a correlated or accompanying change in a physiologically related part of far greater magnitude and prominence to the eye of the human onlooker. This accompanying or correlated character has no selective value, is not an adaptation—is, in fact, a necessary but useless by-product. A list of a few cases of this kind was given by Darwin, but it is most desirable that more should be established. For they enable us to understand how it is that specific characters, those seen and noted on the surface by systematists, are not in most cases adaptations of selective value. They also open a wide vista of incipient and useless developments which may suddenly, in their turn, be seized upon by ever-watchful natural selection and raised to a high pitch of growth and function.

The second, somewhat but by no means altogether neglected, principle is that a good deal of the important variation in both plants and animals is not the variation of a minute part or confined to one organ, but has really an inner physiological basis, and may be a variation of a whole organic system or of a whole tissue expressing itself at several points and in several shapes. In fact, we should perhaps more generally conceive of variation as not so much the accomplishment and presentation of one little mark or difference in weight, length, or colour, as the expression of a *tendency to vary* in a given tissue or organ in a particular way. Thus we are prepared for the rapid extension and dominance of the variation if once it is favoured by selective breeding. It seems to me that such cases as the com-

plete disappearance of scales from the integument of some osseous fishes, or the possible retention of three or four scales out of some hundreds present in nearly allied forms, favour this mode of conceiving of variation. So also does the marked tendency to produce membranous expansions of the integument in the bats, not only between the digits and from the axilla, but from the ears and different regions of the face. Of course, the alternative hairy or smooth condition of the integuments both in plants and animals is a familiar instance in which a tendency extending over a large area is recognised as that which constitutes the variation. In smooth or hairy varieties we do not postulate an individual development of hairs subjected one by one to selection and survival or repression.

Disease.—The study of the physiology of unhealthy, injured, or diseased organisms is called pathology. It necessarily has an immense area of observation and is of transcending interest to mankind who do not accept their diseases unresistingly and die as animals do, so purifying their race, but incessantly combat and fight disease, producing new and terrible forms of it, by their wilful interference with the earlier rule of Nature.

Our knowledge of disease has been enormously advanced in the last quarter of a century, and in an important degree our power of arresting it, by two great lines of study going on side by side and originated, not by medical men nor physiologists in the narrow technical sense, but by naturalists, a botanist, and a zoologist. Ferdinand Cohn, Professor of Botany in Breslau, by his own researches and by personal training in his laboratory, gave to Robert Koch the start on his distinguished career as a bacteriologist. It is to

Metschnikoff the zoologist and embryologist that we owe the doctrine of phagocytosis and the consequent theory of immunity now so widely accepted.

We must not forget that in this same period much of the immortal work of Pasteur on hydrophobia, of Behring and Roux on diphtheria, and of Ehrlich and many others to whom the eternal gratitude of mankind is due, has been going on. It is only some fifteen years since Calmette showed that if cobra poison were introduced into the blood of a horse in less quantity than would cause death, the horse would tolerate with little disturbance after ten days a full dose, and then day after day an increasing dose, until the horse without any inconvenience received an injection of cobra poison large enough to kill thirty horses of its size. Some of the horse's blood being now withdrawn was found to contain a very active antidote to cobra poison—what is called an antitoxin. The procedure in the preparation of the antitoxin is practically the same as that previously adopted by Behring in the preparation of the antitoxin of diphtheria poison. Animals treated with injections of these antitoxins are immune to the poison itself when subsequently injected with it, or, if already suffering from the poison (as, for instance, by snake-bite), are readily shown by experiment to be rapidly cured by the injection of the appropriate antitoxin. This is, as all will admit, an intensely interesting bit of biology. The explanation of the formation of the antitoxin in the blood and its mode of antagonising the poison is not easy. It seems that the antitoxin is undoubtedly formed from the corresponding toxin or poison, and that the antagonism can be best understood as a chemical reaction by which the complex molecule of the poison is upset, or effectively modified.

The remarkable development of Metschnikoff's doctrine of phagocytosis during the past quarter of a century is certainly one of the characteristic features of the activity of biological science in that period. At first ridiculed as 'Metschnikoffism,' it has now won the support of its former adversaries.

For a long time the ideal of hygienists has been to preserve man from all contact with the germs of infection, to destroy them and destroy the animals conveying them, such as rats, mosquitoes, and other flies. But it has now been borne in upon us that, useful as such attempts are, and great as is the improvement in human conditions which can thus be effected, yet we cannot hope for any really complete or satisfactory realisation of the ideal of escape from contact with infective germs. The task is beyond human powers. The conviction has now been arrived at that, whilst we must take every precaution to diminish infection, yet our ultimate safety must come from within — namely, from the activity, the trained, stimulated, and carefully guarded activity, of those wonderful colourless amœba-like corpuscles whose use was so long unrecognized, but has now been made clear by the patiently continued experiments and arguments of Metschnikoff, who has named them 'phagocytes.' The doctrine of the activity and immense importance of these corpuscles of the living body which form part of the all-pervading connective tissues and float also in the blood, is in its nature and inception opposed to what are called the 'humoral' and 'vitalistic' theories of resistance to infection. Of this kind were the beliefs that the *liquids* of the living body have an inherent and somewhat vague power of resisting infective germs, and even that the mere living quality of the tissues was in some unknown way antagonistic to foreign intrusive disease-germs.

The first eighteen years of Metschnikoff's career, after his undergraduate course, were devoted to zoological and embryological investigations. He discovered many important facts, such as the alternation of generations in the parasitic worm of the frog's lung—*Ascaris nigrovenosa*—and the history of the growth from the egg of sponges and medusæ. In these latter researches he came into contact with the wonderfully active cells, or living corpuscles, which in many low forms of life can be seen by transparency in the living animal. He saw that these corpuscles (as was indeed already known) resemble the

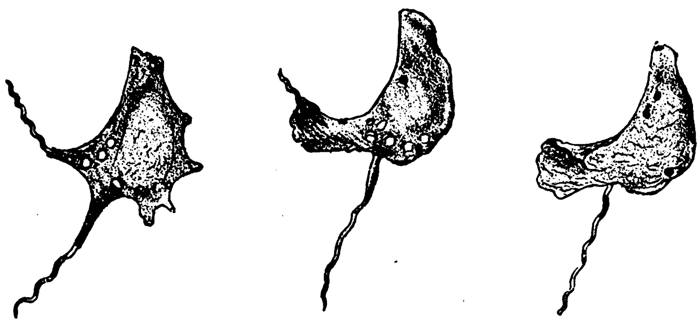


FIG. 37. FIG. 38. FIG. 39.

Fig. 37.—Phagocyte or colourless corpuscle of a guinea-pig in the act of engulphing two Spirilla or parasitic vegetable microbes of a spiral shape. Fig. 38.—The same half an hour later, one of the Spirilla is nearly completely engulphed. Fig. 39.—The same ten minutes later still, one of the Spirilla is completely absorbed into the substance (protoplasm) of the phagocyte. (*From* Metschnikoff's book, "Immunity," kindly supplied by the Cambridge University Press.)

well-known amœba, and can take into their soft substance (protoplasm) at all parts of their surface any minute particles and digest them, thus destroying them. In a transparent water-flea Metschnikoff saw these amœba-like, colourless, floating blood-corpuscles swallowing and digesting the spores of a parasitic fungus which had attacked the water-fleas and was causing their death.

He came to the conclusion that this is the chief, if not the whole, value of these corpuscles in higher as well as lower animals, in all of which they are very abundant.

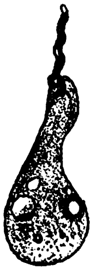


FIG. 40.

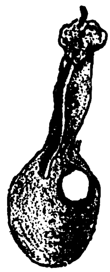


FIG. 41.

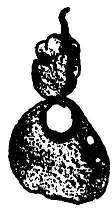


FIG. 42.

Fig. 40.—Phagocyte of a guinea-pig in the course of engulphing a very mobile undulating spirillum. Fig. 41.—The same, forty minutes later. Fig. 42.—The same taken half an hour after Fig. 41. (*From* Metschnikoff's "Immunity.")

It was known that when a wound bringing in foreign matter is inflicted on a vertebrate animal the blood-vessels became gorged in the neighbourhood and the colourless corpuscles escape through the walls of the vessels in crowds. Their business in so doing, Metschnikoff showed,

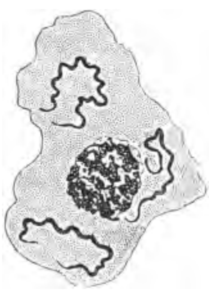


FIG. 43.

A large kind of phagocyte of the guinea-pig, killed and stained for microscopic examination. It shows the large spherical nucleus and three specimens of the spirillum of relapsing-fever which have been engulphed, and are lying within its protoplasm. They would have been slowly digested—that is to say, dissolved by the digestive juices within the phagocyte. (*From* Metschnikoff's "Immunity.")

is to eat up the foreign matter, and also to eat up and remove the dead, wounded tissue. He therefore called these white or colourless corpuscles 'phagocytes,' the

eater-cells, and in his beautiful book on Inflammation, published twenty years ago, proved the extreme importance of their activity. At the same time he had shown that they eat up intrusive bacteria and other germs (see figs. 37 to 43); and his work for the last twenty years has mainly consisted in demonstrating that they are the chief, and probably the only, agents at work in either ridding the human body of an attack of disease-causing germs or in warding off even the commencement of an attack, so that the man or animal in which they are fully efficient is 'immune'—that is to say, cannot be effectively attacked by disease-germs.

Disease-germs, bacteria, or protozoa produce poisons which sometimes are too much for the phagocytes, poisoning them and so getting the upper hand. But, as Metschnikoff showed, the training of the phagocytes by weak doses of the poison of the disease-germ, or by weakened cultures of the disease-germ itself, brings about a power of resistance in the phagocytes to the germ's poison, and thus makes them capable of attacking the germs and keeping them at bay. Hence the value of inoculations.

The discussion and experiments arising from Metschnikoff's demonstrations have led to the discovery of the production by the phagocytes of certain exudations from their substance which have a most important effect in weakening the resistance of the intrusive bacteria and rendering them easy prey for the phagocyte. These are called 'sensitisers,' and have been largely studied. They may be introduced artificially into the blood and tissues so as to facilitate the work of the phagocytes, and no doubt it is a valuable remedial measure to make use of such sensitisers as a treatment. Dr. Wright considers that such sensitisers are formed in the blood and tissues independently of the phagocytes, and has called them 'opso-

nins,' under which name he has made most valuable application of the method of injecting them into the body so as to facilitate the work of the phagocytes in devouring the hostile bacteria of various diseases. Each kind of disease-producing microbe has its own sensitiser or opsonin; hence there has been much careful research and experiment required in order to bring the discovery into practical use. Metschnikoff himself holds and quotes experiments to show that the 'opsonins' are actually produced by the phagocytes themselves. That this should be so is in accordance with some striking zoological facts, as I pointed out nearly twenty years ago.[1] For the lowest multicellular animals provided with a digestive sac or gut, such as the polyps, have that sac lined by digestive cells which have the same amœboid character as 'phagocytes,' and actually digest to a large extent by swallowing or taking into their individual protoplasm raw particles of food. Such particles are enclosed in a temporary cavity, or vacuole, into which the cell-protoplasm secretes digestive ferment and other chemical agents. Now there is no doubt that such digestive vacuoles may burst and so pour out into the polyp's stomach a digestive juice which will act on food particles outside the substance of the cells, and thus by the substitution of this process of out-pouring of the secretion for that of ingestion of food particles into the cells we get the usual form of digestion by juices secreted into a digestive cavity. Now this being certainly the case in regard to the history of the original phagocytes lining the polyp's gut, it does not seem at all unlikely, but on the contrary in a high degree probable, that the phagocytes of the blood and tissues should behave in the same way and pour out

[1] In a review of Metschnikoff's 'Leçons sur l'Inflammation' in *Nature*, 1899.

sensitisers and opsonins to paralyse and prepare their bacterial food. And the experiments of Metschnikoff's pupils and followers show that this is undoubtedly the case. Whether there is any great variety of and difference between 'sensitisers' and 'opsonins' is a matter which is still the subject of active experiment. Metschnikoff's conclusion, as recently stated in regard to the whole progress of this subject, is that the phagocytes in our bodies should be stimulated in their activity in order successfully to fight the germs of infection. Alcohol, opium, and even quinine, hinder the phagocytic action; they should therefore be entirely eschewed or used only with great caution where their other and valuable properties are urgently needed. It appears that the injection of blood-serum into the tissues of animals causes an increase in the number and activity of the phagocytes, and thus an increase in their resistance towards pathogenic germs. Thus Durham (who was a pioneer in his observations on the curious phenomena of the 'agglutination' of blood corpuscles in relation to disease) was led to suggest the injection of sera during surgical operations, and experiments recently quoted by Metschnikoff seem to show that the suggestion was well founded. Both German and French surgeons have employed the method with successful results, and the demonstration that an immense number of microbes are thus taken up and destroyed by the multiplication (due to their regular increase by cell-division) of the phagocytes of the injected patient. After years of opposition bravely met in the pure scientific spirit of renewed experiment and demonstration, Metschnikoff is at last able to say that the foundation-stone of the hygiene of the tissues—the thesis that our phagocytes are our arms of defence against infective germs—has been generally accepted.

Another feature of the progress of our knowledge of disease—as a scientific problem—is the recent recognition that minute animal parasites of that low degree of unicellular structure to which the name 'Protozoa' is given, are the causes of serious and ravaging diseases, and that the minute algoid plants, the bacteria, are not alone in possession of this field of activity. It was Laveran—a French medical man—who, just about twenty-five years ago, discovered the minute animal organism in the red blood-corpuscles, which is the cause of malaria (see fig. 44). Year by year ever since our knowledge of this terrible little parasite has increased. We now know many similar to, but not identical with it, living in the blood of birds, reptiles, and frogs (see fig. 45).

It is the great merit of Major Ross, formerly of the Indian Army Medical Staff, to have discovered, by most patient and persevering experiment, that the malaria parasite passes a part of its life in the spot-winged gnat or mosquito (*Anopheles*), not, as he had at first supposed, in the common gnat or mosquito (*Culex*), and that if we can get rid of spot-winged mosquitoes or avoid their attentions, or even only prevent them from sucking the blood of malarial patients, we can lessen, or even abolish, malaria.

This great discovery was followed by another as to the production of the deadly 'Nagana' horse and cattle disease in South Africa by a screw-like, minute animal parasite *Trypanosoma Brucei* (see fig. 46 B). The Tsetze fly (see fig. 48 A, B), which was already known in some way to produce this disease, was found by Colonel David Bruce to do so by conveying by its bite the Trypanosoma from wild big-game animals, to the domesticated horses and cattle of the colonists. The discovery of the parasite and its relation to the

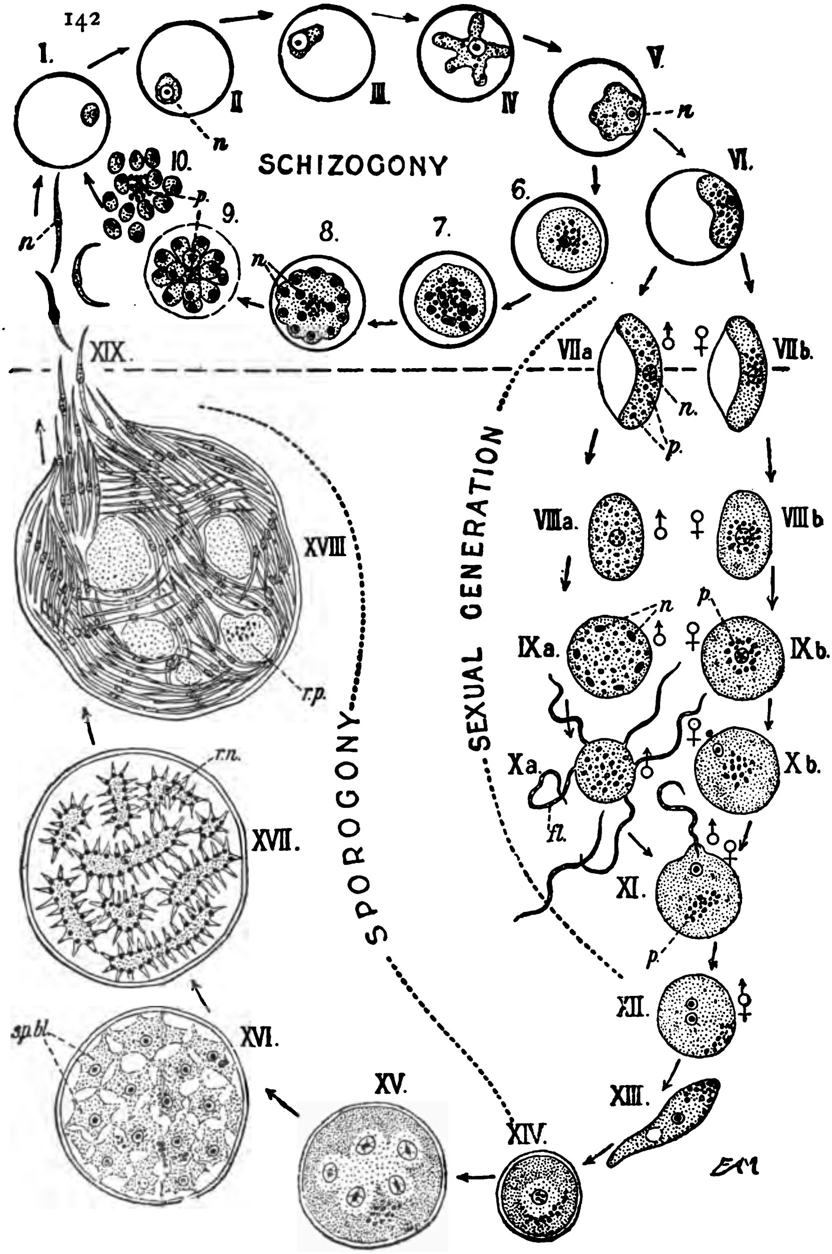

SCHIZOGONY
SEXUAL GENERATION
SPOROGONY
I.
II
III
IV
V.
VI.
6.
7.
8.
9.
10.
n
p.
VIIa
VIIb.
VIIIa.
VIIIb
IXa.
IXb.
Xa.
Xb.
fl.
XI.
XII.
XIII.
XIV.
XV.
XVI.
XVII.
XVIII
XIX.
r.n.
r.p.
sp.bl.

FIG. 44.

FIG. 44.

A diagram showing the life-history and migration of the Malaria parasite, *Laverania Malariæ*, as discovered by Laveran, Ross, and Grassi. The stages above the dotted line take place in the blood of man. The oblong-pointed parasite is seen entering the blood at *n* just below No. I. The circles represent the red blood-discs of man. Schizogony means multiplication by simple division or splitting, and it is seen in Nos. 6, 7, 8, 9, and 10. The stages below the dotted line are passed in the body of the spot-winged gnats of the genus *Anopheles*. A peculiar crescent or sausage-shaped condition is assumed by the parasite inside the red corpuscle No. VI. These are found to be of two kinds, male and female, Nos. VIIa and VIIb. They are swallowed by the spot-winged gnat when it sucks the blood of an infected man. Here in the gut of the gnat they become spherical; the male spheres produce spermatozoa No. Xa, which fuse with and fertilize the female spheres or egg-cells No. XI. An active worm-like form No. XIII results, which pushes its way partly through the wall of the gnat's gut, and is then nourished by the gnat's blood. It swells up, divides internally again and again, and is enclosed in a firm transparent case or cyst, Nos. XIV to XVIII. The cysts are far larger in proportion than is shown in the diagram, and are visible to the naked eye. The final product of the breaking up, which is called sporogony, is a vast number of needle-shaped spores or young (called Exotospores, as opposed to the Enhæmospores, which are formed in the human blood, as seen in Nos. 9 and 10, and serve there to spread the infection among the red corpuscles). The needle-shaped spores formed in the gnat's body accumulate in its salivary glands, and pass out by the mouth of the gnat when it stabs a new human victim who thus becomes infected, No. XIX.

Had the sausage-like phases Nos. VIIa and VIIb been swallowed by a common gnat or mosquito of the genus *Culex* they would have been digested and destroyed. It is only in species of gnats of the kind known as *Anopheles* that the parasite can undergo its sexual development and subsequent process of the formation of cysts and needle-shaped exotospores. (After Minchin in Part I. of Lankester's "Treatise on Zoology," published by A. and C. Black.)

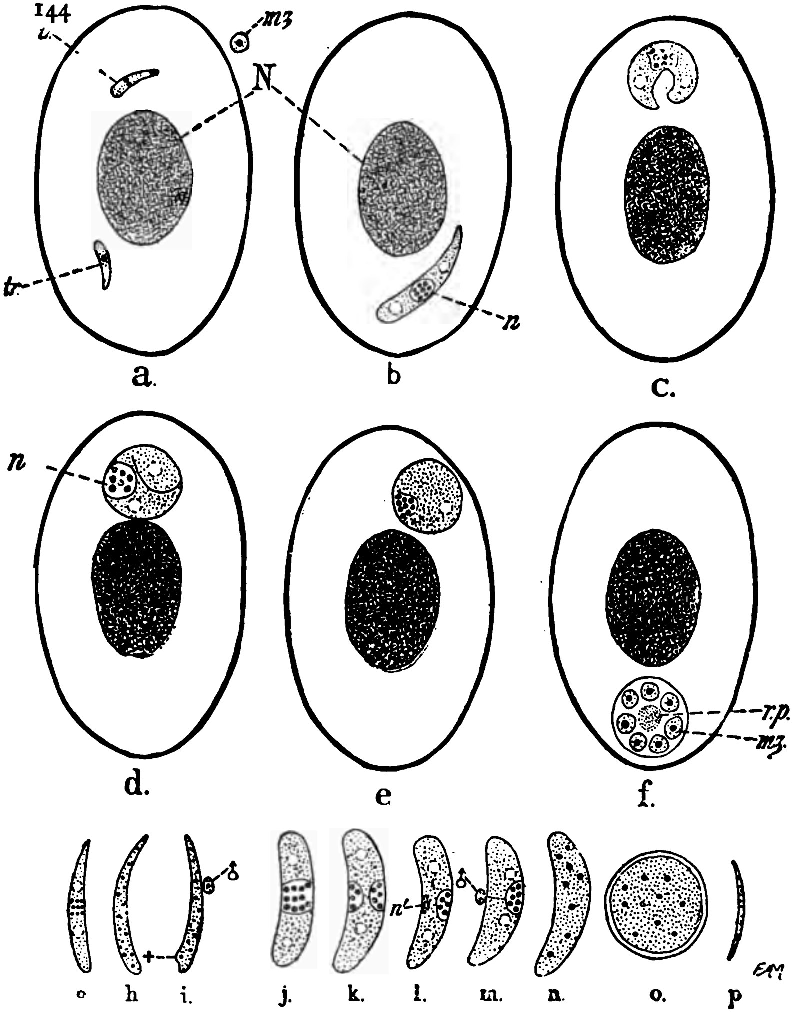


FIG. 45.

Lankesterella ranarum (Lank.), the parasite of the red blood-corpuscles of the edible Frog, described originally as *Drepanidium ranarum* by Lankester in 1882, and previously without name in 1871. The large ovals represent the red corpuscles of the frog; the dark central mass is the nucleus, N. In A two spindle-shaped parasites are seen; in B one larger parasite with nucleus *n* preparing to divide; in C the parasite is V-shaped. In D the parasite has become spherical, and is so in E also. In F the spherical parasite has divided into a number of spores *mz*, with a central residual body *np*. The figures G to N represent supposed stages in conjugation of small and large forms; O is an encysted phase; and P a spore or sporozoite of the sexual generation similar to the needle-shaped exotospores of Laverania. (See Fig. 44.) All the figures magnified 2,250 diameters. (After Hintze from Minchin's section on Sporozoa in Lankester's "Treatise on Zoology.")

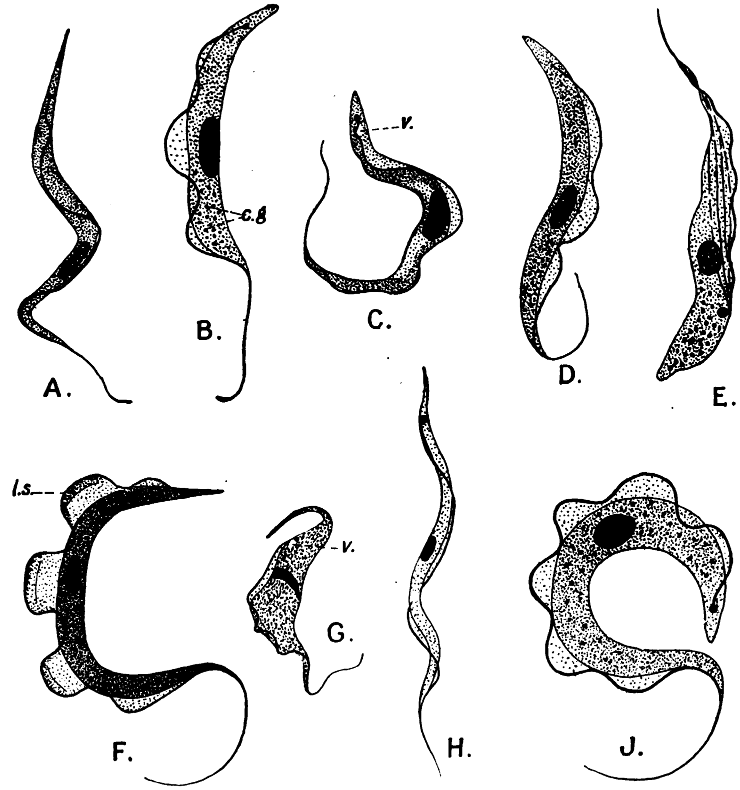


FIG. 46.

Various species of *Trypanosoma* from the blood of mammals, birds, and reptiles. A. *T. Lewisii*, from the blood of rats; B. *T. Brucii*, the parasite of the Nagana or Tsetze-fly disease, found in the blood of horses, cattle, and big game; C. *T. gambiense*, the parasite causing Sleeping Sickness in man; D. *T. equinum*, which causes the *mal de caderas* in South American horse ranches; E. *T. noctuæ*, from the blood of the little owl, *Athene noctua*; F. *T. avium*, found in the blood of many birds; G. a species found in the blood of Indian pigeons; H. *T. ziemanni*, a second species from the blood of the little owl; J. *T. damoniæ*, from the blood of a tortoise; *c.g.*, granules; *v.*, vacuole; *l.s.*, fold of the crest or undulating membrane.

These figures are from Dr. Woodcock's article on the "Hæmo-flagellates" in the *Quarterly Journal of Microscopical Science*, April and June, 1906. (See also the figures in the next chapter relating to Sleeping Sickness.)

fly and the disease was as beautiful a piece of scientific investigation as biologists have ever seen. A curious and very important fact was discovered by Bruce—namely, that the native big game (zebras, antelopes, and probably buffaloes), are *tolerant* of the parasite. The *Trypanosoma* grows and multiplies in their blood, but does not kill them or even injure them. It is only the unaccustomed introduced animals from Europe which are poisoned by the chemical excreta of the Trypanosomes and die in consequence. Hence the wild creatures—brought into a condition of tolerance by natural selection and the dying out of those susceptible to the poison—form a sort of 'reservoir' of deadly Trypanosomes for the Tsetze flies to carry into the blood of new-comers. The same phenomenon of 'reservoir-hosts' (as I have elsewhere called them) has since been observed in the case of malaria; the children of the native blacks in Africa and in other malarious regions are *tolerant* of the malarial parasite, as many as 80 per cent. of children under ten being found to be infected, and yet not suffering from the poison. This is not the same thing as the immunity which consists in *repulsion* or *destruction* of the parasite.

The Trypanosomes have acquired a terrible notoriety within the last four years, since another species, also carried by a Tsetze fly of another species, has been discovered by Castellani in cases of Sleeping Sickness in Uganda, and demonstrated by Colonel Bruce to be the cause of that awful disease.[1] Over 200,000 natives of Uganda have died from it within the last five years. It is incurable, and, sad to relate, not only a certain number of European employés have succumbed to it in tropical Africa, but a brave young officer of the Army Medical

[1] See the next chapter, devoted to this subject.

Corps, Lieutenant Tulloch, has died from the disease acquired by him in the course of an investigation of this disease and its possible cure, which he was carrying out, in association with other men of science, on the Victoria Nyanza Lake in Central Africa. Lieutenant Tulloch was sent out to this investigation by the Royal Society of London, and I will venture to ask my readers to join that body in sympathy for his friends, and admiration for him and the other courageous men who risk their lives in the endeavour to arrest disease.

Trypanosomes are now being recognised in the most diverse regions of the world as the cause of disease—new horse diseases in South America, in North Africa, in the Philippines and East India are all traced to peculiar species of Trypanosome. Other allied forms are responsible for Delhi-sore, and certain peculiar Indian fevers of man. A peculiar and ultra-minute parasite of the blood cells causes Texas fever, and various African fevers deadly to cattle. In all these cases, as also in that of plague, the knowledge of the carrier of the disease, often a tick or acarid—in that of plague the flea of the rat—is extremely important, as well as the knowledge of reservoir-hosts when such exist.

The zoologist thus comes into closer touch than ever with the profession of medicine, and the time has arrived when the professional students of disease fully admit that they must bring to their great and hopeful task of abolishing the diseases of man the fullest aid from every branch of biological science. I need not say how great is the contentment of those who have long worked at apparently useless branches of science—such as are the careful and elaborate distinction of every separate kind of animal and the life-history and structure peculiar to each—in the belief that all knowledge is good, to find that

the science they have cultivated has become suddenly and urgently of the highest practical value.

I have not time to do more than mention here the effort that is being made by combined international research and co-operation to push further in our knowledge of phthisis and of cancer, with a view to their destruction. It is only since our last meeting at York that the parasite of Phthisis or Tubercle has been made known; we may hope that it will not be long before we have similar knowledge as to Cancer. Only eighteen months have elapsed since Fritz Schaudinn discovered the long-sought parasitic germ of Syphilis, the *Spirocheta pallida* (see fig. 6). As I write these words the sad news of Schaudinn's death at the age of thirty-five comes to me from his family at Hamburg—an irreparable loss.

Let me finally state, in relation to this study of disease, what is the simple fact—namely, that if the people of Britain wish to make an end of infective and other diseases they must take every possible means to discover capable investigators, and employ them for this purpose. To do this, far more money is required than is at present spent in that direction. It is necessary, if we are to do our utmost, to spend a thousand pounds of public money on this task where we now spend one pound. It would be reasonable and wise to expend ten million pounds a year of our revenues on the investigation and attempt to destroy disease. Actually what is so spent is a mere nothing, a few thousands a year. Meanwhile our people are dying by thousands of preventable disease.

2. The Advancement of Science as Measured by the Support given to it by Public Funds, and the Respect Accorded to Scientific Work by the British Government and the Community at Large.

Whilst I have been able, though in a very fragmentary and incomplete way, to indicate the satisfactory and, indeed, the wonderful progress of science in the last quarter of a century, so far as the making of new knowledge is concerned, I am sorry to say that there is by no means a corresponding 'advancement' of Science in that signification of the word which implies the increase of the influence of science in the life of the commuity, the increase of the support given to it, and of the desire to aid in its progress, to discover and then to encourage and reward those who are specially fitted to increase scientific knowledge, and to bring it to bear so as to promote the welfare of the community.

It is, unfortunately, true that the successive political administrators of the affairs of this country, as well as the permanent officials, are altogether unaware to-day, as they were twenty-five years ago, of the vital importance of that knowledge which we call science, and of the urgent need for making use of it in a variety of public affairs. Whole departments of Government in which scientific knowledge is the one thing needful are carried on by ministers, permanent secretaries, assistant secretaries and clerks who are wholly ignorant of science, and naturally enough dislike it, since it cannot be used by them, and is in many instances the condemnation of their official employment.

Such officials are, of course, not to be blamed, but rather the general indifference of the public to the unreasonable way in which its interests are neglected.

A difficult feature in treating of this subject is that when one mentions the fact that ministers of State and the officials of the public service are not acquainted with science, and do not even profess to understand its results or their importance, one's statement of this very obvious and notorious fact is apt to be regarded as a personal offence. It is difficult to see wherein the offence lies, for no one seeks to blame these officials for a condition of things which is traditional and frankly admitted.

This is really a very serious matter for the scientific world to consider and deal with. We represent a line of activity, a group of professions which are in our opinion of vital importance to the well-being of the nation. We know that those interests which we value so highly are not merely ignored and neglected, but are actually treated as of no account or as non-existent by the old-established class of politicians and administrators. It is not too much to say that there is a natural fear and dislike of scientific knowledge on the part of a large proportion of the persons who are devoid of it, and who would cease to hold, or never have held, the positions of authority or emolument which they now occupy, were scientific knowledge of the matters with which they undertake to deal required of them. This is a thorny subject, and one in which, however much one may endeavour to speak in general terms, it is difficult to avoid causing personal annoyance. Yet it seems to me one of urgent importance. Probably an inquiry into and discussion

of the neglect of science and the questionable treatment of scientific men by the administrative departments of Government might with advantage be undertaken by a committee appointed by our great scientific societies for the purpose.

At the same time public attention should be drawn in general terms to the fact that science is not gaining 'advancement' in public and official consideration and support. The reason is, I think, to be found in the defective education, both at school and university, of our governing class, as well as in a racial dislike among all classes to the establishment and support by public funds of posts which the average man may not expect to succeed by popular clamour or class privilege in gaining for himself—posts which must be held by men of special training and mental gifts. Whatever the reason for the neglect, the only remedy which we can possibly apply is that of improved education for the upper classes, and the continued effort to spread a knowledge of the results of science and a love for it amongst all members of the community. If believers in science took this matter seriously to heart they might do a great deal by insisting that their sons, and their daughters too, should have reasonable instruction in science both at school and college. They could, by their own initiative and example, do a good deal to put an end to the trifling with classical literature and the absorption in athletics which is considered by too many schoolmasters as that which the British parent desires as the education of his children.

Within the past year a letter has been published by a well-known nobleman, who is one of the Trustees of the British Museum, holding up to public condemnation the method in which the system laid down by the officials of the Treasury and sanctioned by successive Governments,

as to the remuneration of scientific men, was applied in an individual case. I desire to place on record here the Earl of Crawford's letter to the 'Times' of October 31, 1905, for the careful consideration of those who desire the advancement of science. When such things are done, science cannot be said to have advanced much in public consideration or Governmental support.

To the Editor of the 'Times.'

SIR,—The death, noted by you to-day, of my dear friend and colleague Dr. Copeland, His Majesty's Astronomer for Scotland, creates a vacancy in the scientific staff of Great Britain.

Will you permit me, Sir, to offer a word of warning to any who may be asked to succeed him ?

Students or masters of astronomy are not, in the selfish sense, business men, nor are they as a general rule overburdened with this world's goods. It behoves them henceforth to take more care as to their future in case of illness or physical infirmity and not to trust to the gratitude or generous impulse of the Treasury Department.

In old days it was the custom when a man distinguished in science was brought into a high position in the Civil Service that he was credited with a certain number of years' service ranking for pension. This practice has been done away with, and a bargain system substituted. A short while ago the growing agonies of heart disease caused Dr. Copeland to feel that he was less able to carry on the duties of his post, and he determined to resign ; but he learnt that under the scale, and in the absence of any special bargain, the pension he would receive would not suffice for the necessities of life. The only increase his friends could get from the Treasury was an offer to allow him about half-a-crown a week extra by way of a house.

Indignant and ashamed of my Government, I persuaded Dr. Copeland to withdraw his resignation and to retain the official position which he has honoured till his death.

I trust, Sir, that this memorandum of mine may cause eminent men of science who are asked to enter the service of the State when already of middle age to take heed for their future welfare.

I am, Sir, your obedient servant,

CRAWFORD.

2 Cavendish Square, October 28.

It is more agreeable to me not to dwell further on the comparative failure of science to gain increased influence and support in this country, but to mention some instances on the other side of the account. As long ago as 1842 the British Association took over and developed an observatory in the Deer Park at Kew, which was placed at the disposal of the Association by Her Majesty the Queen. Until 1871 the Association spent annually a large part of its income—as much in later years as 600*l.* a year—in carrying on the work of the Kew Observatory, consisting of magnetic, meteorological and physical observations. In 1871 the Association handed over the Observatory to the Royal Society, which had received an endowment of 10,000*l.* from Mr. Gassiot for its maintenance, and had further devoted to that purpose considerable sums from its own Donation Fund and Government Grant. Further aid for it was also received from private sources. From this Observatory at last has sprung, in the beginning of the present century, the National Physical Laboratory in Bushey Park, a fine and efficient scientific institution, built and supported by grants from the State, and managed by a committee of really devoted men of science who are largely representatives of the Royal Society. In addition to the value of the site and buildings occupied by the National Physical Laboratory, the Government has contributed altogether 34,000*l.* to the capital expenditure on new buildings, fittings, and apparatus, and has further assigned a grant of 6,000*l.* a year to the working of the laboratory. This institution all men of science are truly glad to have gained from the State, and they will remember with gratitude the statesmen—the late Marquis of Salisbury, the Right Hon. Arthur J. Balfour, Mr. Haldane, and others—as well as their own leaders—Lord Rayleigh, Sir William Huggins, and the active body of

physicists in the Royal Society who have carried this enterprise to completion. The British Association has every reason to be proud of its share in early days in nursing the germ at Kew which has at length expanded into this splendid national institution.

I may mention also another institution which, during the past quarter of a century, has come into existence and received, originally through the influence of the late Lord Playfair (one of the few men of science who has ever occupied the position of a Minister of the Crown), and later by the influence of the Right Hon. Joseph Chamberlain, a subsidy of 1,000*l.* a year from the Government and a contribution of 5,000*l.* towards its initial expenses. This is the Marine Biological Association,[1] which has a laboratory at Plymouth (see fig. 47), and has lately expended a special annual grant, at the spontaneous invitation of His Majesty's Treasury, in conducting an investigation of the North Sea in accordance with an international scheme devised by a central committee of scientific experts. This scheme has for its purpose the gaining such knowledge of the North Sea and its inhabitants as shall be useful in dealing practically and by legislation with the great fisheries of that area. The reader will, perhaps, not be surprised to hear that there are persons in high positions who, though admittedly unacquainted with the scientific questions at issue or the proper manner of solving them, are discontented with the action of the Government in entrusting the expenditure of public money to a body of

[1] I had the honour and good fortune to found this association and to collect the funds so generously given to it—then for many years to act as its honorary secretary, to design and superintend the erection of the laboratory and to organize, in conjunction with my scientific colleagues, its staff, its scheme of work and government. On the death of our beloved president, Professor Huxley, I was elected as his successor, and still occupy that position.

scientific men who give their services, without reward or thanks, to carrying out the purposes of the international inquiry. Strange criticisms are offered by these mal-

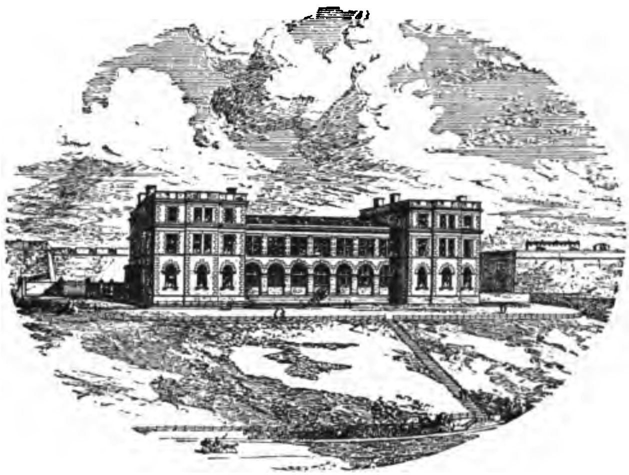


FIG. 47.

The Laboratory of the Marine Biological Association on the Citadel Hill, Plymouth, overlooking Plymouth Sound. The laboratory was built with the aid of funds raised by public subscription and a contribution of £5,000 by H.M. Government, and cost £12,200. The Association has expended, exclusive of this sum, since the opening of the laboratory in 1884, about £62,000, or an average of £3,000 a year on the maintenance of the laboratory, steam-boat and fishing-boats, and in payment of a staff of scientific observers. Of this sum the Government has contributed one-third, the rest has come from private donations and subscriptions, and from the "earnings" of the laboratory by sale of specimens, admission fees to the tank-room, &c. The journal of the Association, published at intervals, records a vast amount of scientific work, advancing our knowledge of marine life and of the life-history of fishes.

In addition to the above expenditure and results, the Association has superintended and most carefully directed the expenditure of £5,000 a year during the past five years in the investigation of the southern area of the North Sea and of the Channel at the request of H.M. Government, the work being part of the International Investigation of the North Sea. The very voluminous results of these inquiries are published in special reports by the International Committee. Full particulars of the work of the Marine Biological Association can be obtained from Dr. E. J. Allen, the Director, the Laboratory, Citadel Hill, Plymouth, who will also receive donations and applications for membership of the Association.

contents in regard to the work done in the international exploration of the North Sea, and a desire is expressed to secure the money for expenditure by a less scientific agency. I do not hesitate to say here that the results obtained by the Marine Biological Association are of great value and interest, and, if properly continued and put to practical application, are likely to benefit very greatly the fishery industry; on the other hand, if the work is cut short or entrusted to incompetent hands it will no doubt be the case that what has already been done will lose its value—that is to say, will have been wasted. There is imminent danger of this perversion of the funds assigned to this scientific investigation taking place. There is no guarantee for the continuance of any funds or offices assigned to science in one generation by the officials of the next. The Mastership of the Mint held by Isaac Newton, and finally by the great chemist Thomas Graham, has been abolished and its salary appropriated by non-scientific officials. Only a few years ago it was with great difficulty that the Government of the day was prevented from assigning the Directorship of Kew Gardens to a young man of influence devoid of all knowledge of botany!

One of the most solid tests of the esteem and value attached to scientific progress by the community is the dedication of large sums of money to scientific purposes by its wealthier members. We know that in the United States such gifts are not infrequent; they are rare in this country. It is, therefore, with especial pleasure that I call attention to a great gift to science in this country made only a few years ago. Lord Iveagh has endowed the Lister Institute, for researches in connection with the prevention of disease, with no less a sum than a quarter of a million pounds sterling. This is the largest gift ever

made to science in this country, and will be productive of great benefit to humanity. The Lister Institute took its origin in the surplus of a fund raised (at my suggestion and with my assistance as secretary) by Sir James Whitehead when Lord Mayor, some sixteen years ago, for the purpose of making a gift to the Pasteur Institute in Paris, where many English patients had been treated, without charge, after being bitten by rabid dogs. Three thousand pounds was sent to M. Pasteur, and the surplus of a few hundred pounds was made the starting-point of a fund which grew, by one generous gift and another, until the Lister Institute on the Thames Embankment at Chelsea was set up on a site presented by that good and high-minded man, the late Duke of Westminster.

Many other noble gifts to scientific research have been made in this country during the period on which we are looking back. Let us be thankful for them, and admire the wise munificence of the donors. But none the less we must refuse to rely entirely on such liberality for the development of the army of science, which has to do battle for mankind against the obvious disabilities and sufferings which afflict us and can be removed by knowledge. The organisation and finance of this army should be the care of the State.

It is a fact which many who have observed it regret very keenly, that there is to-day a less widespread interest than formerly in natural history and general science, outside the strictly professional arena of the school and university. The field naturalists among the squires and the country parsons seem nowadays not to be so numerous and active in their delightful pursuits as formerly, and the Mechanics' Institutes and Lecture Societies of the days of Lord Brougham have given place, to a very large extent, to musical performances, bioscopes, and other

entertainments, more diverting, but not really more capable of giving pleasure than those in which science was popularised. No doubt the organisation and professional character of scientific work are to a large extent the cause of this falling-off in its attraction for amateurs. But perhaps that decadence is also due in some measure to the increased general demand for a kind of manufactured gaiety, readily sent out in these days of easy transport from the great centres of fashionable amusement to the provinces and rural districts.

Before concluding this retrospect, I would venture to allude to the relations of scientific progress to religion. Putting aside the troubles connected with special creeds and churches and the claims of the clerical profession to certain funds and employments to the exclusion of laymen, it should, I think, be recognized that there is no essential antagonism between the scientific spirit and what is called the religious sentiment. 'Religion,' said Bishop Creighton, 'means the knowledge of our destiny and of the means of fulfilling it.' We can say no more and no less of Science. Men of Science seek, in all reverence, to discover the Almighty, the Everlasting. They claim sympathy and friendship with those who, like themselves, have turned away from the more material struggles of human life, and have set their hearts and minds on the knowledge of the Eternal.

CHAPTER III.

NATURE'S REVENGES: THE SLEEPING SICKNESS.

AMONG the strange and mysterious diseases to which mankind is subject in regions less familiar to the civilised world than Western Europe, none is stranger or more appalling in its quiet, inexorable deadliness than the Sleeping Sickness of the West African coast. Apparently it has existed among the natives of that region from time immemorial; but the first printed record we have of it is due to Winterbottom, who, writing in 1803 of Sierra Leone, said, "The Africans are very subject to a species of lethargy which they are much afraid of, as it proves fatal in every instance." One of the latest notices of the disease, before it became the subject of active investigation within the last five years, is that of Miss Kingsley, who saw a few cases near the Congo estuary, but, though she was impressed by the mysterious fatality of the disease, she did not describe it as very prevalent or as a general source of danger to life. The opening up of the Congo basin and increased familiarity with the inner lands of the West African coast have shown that this disease is widely scattered—though rarely so abundant as to be a serious scourge—through the whole of tropical West Africa. Writers in the early part of the last century described the disease as occurring in the West Indies and in Brazil. Its presence was almost certainly due, in those days of the slave trade, to the importation

of negroes already infected with the disease; and a curious theory obtained some favour, according to which the sleeping sickness of the West Indian slaves was a kind of nostalgia, and, in fact, the manifestation of what is sometimes called "a broken heart."

The signs that a patient has contracted the disease are very obvious. They are recognised by the black people, and the certainly fatal issue accepted with calm acquiescence. The usually intelligent expression of the healthy negro is replaced by a dull apathetic appearance; and there is a varying amount of fever and headache. This may last for some weeks but is followed more or less rapidly by a difficulty in locomotion and speech, a trembling of the tongue and hands. There is increased fever and constant drowsiness, from which the patient is roused only to take food. At last—usually after some three or four months of illness —complete somnolence sets in; no food is taken; the body becomes emaciated and ulcerated; and the victim dies in a state of coma. The course of the disease, from the time when the apathetic stage is first noticed, may last from two to twelve months.

It is this terrible disease which has lately appeared on the shores of the Victoria Nyanza, in the kingdom of Uganda, administered by the British Government. Until the early part of the year 1901 there was not the slightest suspicion that sleeping sickness occurred in any part of the Uganda Protectorate; nor was it known in East Africa at all, any more than in the north and south of that great continent. It seems gradually to have crept up the newly opened trade-routes of the Congo basin, and thence to have spread into the west of Uganda, the territory known as Busoga. Numbers of Soudanese and Congo men are known to have settled in this region after

the death of Emin Pasha. First noticed in 1901, it was estimated in June 1902, by the Commissioner of Uganda, writing officially to the Marquess of Lansdowne, that 20,000 persons had died of this disease in the district of Busoga alone, and several thousands in the more eastern portion of Uganda. At this moment it is probable that the number of deaths in this region due to sleeping sickness since 1901 amounts to more than 200,000; and this though, most fortunately, the disease has not yet spread eastward from Uganda into British East Africa,[1] nor, so far as has been reported, down the Nile. No curative treatment for the disease has yet been discovered; nor is there any authenticated instance of recovery.

The appalling mortality produced by this disease in Central Africa naturally caused the greatest anxiety to his Majesty's Government, which had but just completed the railway from the East Coast to the shores of lake Victoria Nyanza, and had established a prosperous and happy rule in that densely populated region. The official medical men on the spot, though capable and experienced practitioners, were unable to cope with this new and virulent outbreak. The Foreign Office, having no imperial board of hygiene and medical administration to apply to in this country, sought the assistance of the Royal Society of London.

A committee of that society had already undertaken the study of malaria at the request of the Secretary of State for the Colonies, and had sent out young medical men as a commission to make certain enquiries and

[1] The disease has actually entered into the administrative area known as British East Africa, but has not made any rapid progress towards the coast. According to a report by Dr. Wiggins, the disease is confined in British East Africa, as in Uganda, to those areas in which *Glossina palpalis* occurs.

experiments on that subject and report to the committee in London. The sleeping sickness enquiry was undertaken by the same committee; but unfortunately very insufficient funds were placed at its disposal. When the South African cattle-owners found their herds threatened six years ago by a new form of mortal disease—'the East Coast fever'—the South African Government accepted the offer of Dr. Robert Koch, of Berlin, to undertake the investigation of the disease and the discovery, if possible, of a remedy, for the sum of £10,000. No such sum was at the disposal of the committee of the Royal Society. They were obliged to send out young and enterprising medical men, practically without pay or reward, to see what they could do in the way of determining the cause of, and, if possible, the remedy for, the terrible sleeping sickness raging in Uganda and destroying daily hundreds of British subjects. The committee set to work in the summer of 1902, and sent out Drs. Low, Christy, and Castellani to Entebbe, the capital of Uganda.

The guesses as to the cause and nature of sleeping sickness at the time when this commission set forth were very various. Some highly capable medical authorities held that it was due to poisonous food. The root of the manioc, on which the natives feed, was supposed to become infected by some poison-producing ferment. A more generally received opinion was that it was caused by a specific bacterium which invades the tissues of the brain and spinal cord. Several totally different micro-organisms of this sort had been described with equal confidence by French and Portuguese investigators as the cause of the sleeping sickness studied by them in West Africa or on the Congo. Sir Patrick Manson, the head of the British Colonial medical service, an authority of

great experience in tropical disease, had put forward the suggestion that the sleeping sickness was due to the infection of the patient by a minute thread worm (allied to the 'vinegar-eel,' and one of a great class of parasites) which he had discovered in the blood of negroes and had named *Filaria perstans*.

The occurrence of minute worms (true worms, neither unicellular plants nor protozoa) in the blood of man was first made known by Dr. Timothy Lewis, who described the *Filaria sanguinis hominis*, as well as some other most important blood-parasites, some years ago (1878), when officially engaged in an enquiry into the cause of cholera in Calcutta. Subsequently, in China, Manson found that these little blood-worms were sucked up by mosquitoes when gorging themselves on the blood of a patient. It is, indeed, difficult to imagine how they should escape passing into the mosquito with the blood. Manson suggested that the minute worms (known to be the embryos of a worm which, when adult, is about one fifteenth of an inch long) are obliged to pass through a mosquito in order to accomplish their development; but no proof of this suggestion has ever been made. We know by abundant and repeated demonstration and experiment that another blood-parasite—the malaria parasite—must pass through a mosquito, in whose body it develops, and by which it is carried to a new victim of infection. This was suspected long ago by both peasants and doctors, and experimentally proved by Ross; but no such proof has been given of the relation of Lewis's blood-worm to a mosquito. The so-called *Filaria perstans*, discovered by Manson in the blood of negroes, appears to be very different from the *Filaria sanguinis hominis* of Lewis. It is not known how it gets into the blood; and it is very astonishing, and much to be regretted, that none of the

medical men who have had it under observation have given a proper anatomical account of it. It appears that this worm is very common in the blood of negroes in tropical Africa; and as it was found in several cases in the blood of individuals attacked by sleeping sickness, Sir Patrick Manson was justified in entertaining the view that this parasite was the cause of the disease.

One of the first results obtained by the commission sent by the Royal Society committee to Uganda was the proof—which had, indeed, been already furnished by the resident medical officers of the Uganda Protectorate—that *Filaria perstans,* though remarkably abundant in the blood of the negroes of Uganda, can have nothing to do with sleeping sickness, since, though it often occurs in persons attacked with that disease, it also exists in districts where sleeping sickness is unknown; and, further, many cases of sleeping sickness have been observed in which no *Filaria perstans* has been discovered in the blood or other parts of the body.

While Drs. Low and Christy occupied themselves with settling this question as to the connexion of *Filaria perstans* with the disease and carried out a careful study of its clinical aspects, Dr. Castellani examined the brain and spinal cord of those who died from sleeping sickness, for bacteria. He found again and again an extremely minute globular vegetable parasite—of the kind known as streptococcus—which he concluded to be the cause of the disease, although he had not produced the disease experimentally by inoculating an animal with this microbe.

In the early part of 1903 these were the only results obtained by some six months' work of the medical men sent out by the Royal Society's committee; and it was felt that something more must be done. The investigation of a disease hitherto little known and studied is one of

the most difficult tasks in the world, requiring the highest scientific qualities. Any serious attempt to deal with the sleeping sickness in Uganda would, it was at length recognised, require the dispatch of a man of proved capacity and experience, provided with full powers and with trained men as his assistants. No such men are provided by the public service of the British Empire. To detach a medical man of recognised insight and experimental skill from his practice—even were it possible to find one specially qualified for the present enquiry—would involve the payment of a large fee, which neither the Royal Society nor the Foreign Office could command.

What, then, was to be done? Fortunately there was one man in the public service, recently appointed to be one of the chiefs of the educational arrangements of the Army Medical Department, who had shown himself to be especially gifted in the investigation of obscure diseases. This was Colonel David Bruce, F.R.S., who, some fifteen years ago, established the existence of Malta fever, as an independent disease, by his clinical observations and by the isolation and cultivation of the parasitic bacterium causing it; and who, further, when employed by the governor of Zululand a few years later (1895) to investigate the celebrated tsetze-fly disease of South Africa, had discovered, contrary to the assertions and prejudices of a large number of African sportsmen and explorers, that the horse and cattle disease known as nagana or tsetze-fly disease was due to the presence in the blood of the affected animals of a peculiar cork-screw-like animal parasite, the *Trypanosoma Brucei*. This is carried by the bite of the tsetze-fly from the blood of wild game, such as buffalo and antelope, where it does no harm, to the blood of domesticated animals, in which it multiplies and proves to be the source of a deadly poison causing death in a few

weeks. The experiments by which Colonel Bruce demonstrated this relationship of tsetze-fly, trypanosome parasite, wild big game, and domesticated animals, were universally regarded as masterly both in conception and execution, and absolutely conclusive.

The committee of the Royal Society came to the conclusion that the thing to be done was to get Colonel Bruce to consent to proceed to Uganda, and to recommend the Foreign Office to obtain from the War Office the temporary detachment of Colonel Bruce for this service. Accordingly Colonel Bruce arrived in Uganda in the middle of March, 1903. Dr. Low and Dr. Christy had already departed, but Dr. Castellani was still at Entebbe engaged in the study of his streptococcus. He mentioned to Colonel Bruce on his arrival that he had on more than one occasion seen a trypanosome in the cerebro-spinal fluid of negroes suffering from sleeping sickness; but, inasmuch as Dutton on the West Coast and Hodges in Uganda had described a trypanosome as an occasional parasite in human blood, he had not considered its occurrence in sleeping-sickness patients as of any more significance than is the occurrence of *Filaria perstans*. Castellani regarded the trypanosome, like the filaria, as a mere accidental concomitant of sleeping sickness, the cause of which he considered to be the bacterial streptococcus which he had so frequently found to be present.

Naturally enough, Bruce was impressed by the fact that trypanosomes, of the deadly nature of which he had had ample experience, had been found, even once, in the cerebro-spinal fluid of sleeping-sickness patients; and he immediately set to work to make a thorough search for this parasite in all the cases of sleeping sickness; then under observation at Entebbe. He generously allowed

Castellani to take part in the investigation, which resulted in the immediate discovery of the trypanosome in the cerebro-spinal fluid of twenty cases, out of thirty-four examined, of negroes afflicted with the disease; whilst in twelve negroes free from sleeping sickness the trypanosome could not be found in the cerebro-spinal fluid. Castellani returned to Europe three weeks after Bruce's experiments were commenced, and announced the discovery, which has been, in consequence, erroneously attributed to him, although mainly due to Bruce.

Bruce continued his work in Uganda until the end of August, 1903, having been joined there by Colonel Greig of the Indian Army, who has continued the work of the Royal Society's commission since Bruce left. Other valuable observations have been carried out by various medical men officially connected with the Uganda Protectorate. Bruce soon showed that in every case of sleeping sickness, when examined with sufficient care, the trypanosome parasite is found to be present in the cerebro-spinal fluid. He also showed that it is absent from that fluid in all negroes examined who were not afflicted with the disease, but made the very important discovery that the trypanosome is present in the blood (not the cerebro-spinal fluid) of twenty-eight per cent. of the population in those areas where sleeping sickness occurs, the persons thus affected having none of the symptoms of sleeping sickness, but being either perfectly healthy or merely troubled with a little occasional fever. The subsequent history of all the cases thus observed has not as yet been recorded. But in many such, even in some Europeans, the earlier presence of the trypanosome in the blood has been followed by its entry into the cerebro-spinal lymphatics, and by the fatal development of sleeping sickness.

As already indicated, it was found by Bruce, on recording the cases of sleeping sickness brought into or reported in Entebbe, that there were certain "sleeping-sickness areas" and other areas free from sleeping sickness. The theory now took shape in Bruce's mind that the trypanosome first gets into the blood, and then after a time, makes its way into the cerebro-spinal system, only then producing its deadly symptoms. Very generally, when once in the blood, the trypanosome multiplies itself, and sooner or later—apparently, in some cases, even after two or three years—gets into the cerebro-spinal fluid. It is probable that it may be destroyed by natural processes in the human body before this final stage is reached; and thus the infected person may recover and escape the deadly phase of the disease. But nothing certain is known, as yet, on this head. Later observations show that the trypanosome is found alive and in large quantity in the lymphatic glands, especially those in the region of the neck in infected persons. These glands were known to be enlarged in persons suffering from the disease.

Colonel Bruce's next step was to ascertain the mode in which the trypanosome is introduced into the blood. Naturally he looked for a kind of tsetze fly, such as carries the trypanosome in the nagana disease of horses and cattle already studied by him in Zululand. It is a fact that the *Glossina morsitans* and *Glossina pallidipes*, which are the tsetze flies of the "fly-districts" where nagana disease is rife, are unknown in Central or Western Africa; and also it is a fact that no tsetze fly had been observed in the neighbourhood of the Victoria Nyanza when Colonel Bruce began his enquiries. He employed, through the good-will of the native chiefs and rulers, a large number of natives to

collect flies throughout the country forming a belt of twenty or thirty miles around the north of the lake. Many thousands of flies were thus brought in, and the localities from which they came carefully noted. Among these flies Colonel Bruce recognised a tsetze fly; and when these collections were received at the Natural History Museum in London, it was at once determined by Mr. Austen, the assistant in charge of our collections of Diptera (or two-winged flies), that the Uganda tsetze fly was not the same species as that of Zululand and the fly country, but a distinct species previously known only on the West Coast and the Congo basin, and described by the name *Glossina palpalis*. The story thus developed itself: the trypanosome of sleeping sickness is probably carried by this West Coast tsetze fly just as the trypanosome of nagana is carried in the south-east of Africa by the *Glossina morsitans* and *pallidipes*, the regular and original "tsetze" flies.

Sleeping sickness thus presented itself as a special kind of human tsetze-fly disease. To test this hypothesis, Colonel Bruce pursued two very important and distinct lines of enquiry. In the first place he found that those places on his map which were marked as "sleeping-sickness areas" were precisely those places from which the collected flies included specimens of tsetze fly, whilst he found that there were no tsetze flies in the collections of flies brought in by the natives from the regions where there was no sleeping sickness.

His second test inquiry consisted in ascertaining whether the tsetze flies of Uganda are actually found, experimentally, to be capable of carrying the trypanosome from one infected person to another. For this purpose it was necessary to make use of monkeys, certain species of which were ascertained to be liable to the infection of

the sleeping sickness trypanosome when this was introduced by means of injection through a syringe. Such monkeys were found to develop the chief symptoms of sleeping sickness, and ultimately died of the disease, their cerebro-spinal fluid being invaded by the parasites. Accordingly it was possible to use monkeys as test animals. It was found by Colonel Bruce that tsetze flies (*Glossina palpalis*) which had been made to bite infected negroes could carry the infection to the monkeys; and it was also found that even when a number of tsetze flies, not specially prepared, were allowed to bite a monkey, the latter eventually developed the trypanosome in its blood and cerebro-spinal fluid, thus showing that the tsetze flies, as naturally occurring in the country around Entebbe, contain many of them, the trypanosome ready to pass from the fly to a human or simian victim, when casually bitten by the fly.

Experiments such as these of infection by the fly, and the use of monkeys in the research, require very great care; and it is quite reasonable to ask that they shall be repeated and most carefully checked before they are considered as demonstrative and absolutely certain. It may, however, be considered as practically certain that the sleeping sickness is due to the presence in the cerebro-spinal fluid of quantities of a minute parasite, the *Trypanosoma Gambiense*, which is carried from man to man by the *palpalis* tsetze fly, which sucks it up from the blood of an infected individual and conveys it to previously uninfected individuals. The natives in Uganda lie about and sleep under the shade of trees where the tsetze flies are especially abundant; and they are quite indifferent to the bites of flies of one kind and another.

It is the dislike to the mere touch of a fly, still more to its bite, which has protected Europeans almost entirely

from the sleeping sickness. Unfortunately there is no immunity for Europeans in the matter; and the existence of half a dozen or more cases of white people infected with the trypanosome, who have ultimately died in England or elsewhere in Europe from sleeping-sickness contracted through the bite of a fly in Africa, is abundant proof that there is not, as has been supposed, any special freedom from the disease for white people [1]

The foregoing description of the nature and mode of the infection of sleeping sickness will not cause any astonishment to the layman of the present day who knows anything of recent medical science. We are all familiar with the danger of fly-bites, even in this country, where deadly bacteria are occasionally carried by biting flies, such as the horse-flies, into the human subject; and nowadays every one is more or less familiar with the discovery of the minute blood-parasite which causes malaria or ague and is carried by a particular kind of gnat in the interior of which it multiplies by a process of sexual conjugation. At the same time the reader who is interested in sleeping sickness will probably desire to know more about the nature of the tsetze flies and some further details as to the parasite spoken of as trypanosome.

The tsetze flies form a genus called by Wiedemann (in 1830) "Glossina." They are only found in Africa; and some seven species in all are known. They are little bigger than a common house-fly, and much like it in colour (fig. 48). They differ in appearance from the house-fly in the fact

[1] Only last year (1905) Lieut. Tulloch, of the Army Medical Department, who with Professor Minchin was engaged in carrying on further researches for the Royal Society on the sleeping sickness at Entebbe in Uganda, became infected by the trypanosome, probably through an unobserved bite by a tsetze fly, and died of the disease soon after his return to England.

that the wings, when the insect is at rest, are parallel to one another, and slightly over-lap in the middle line, instead being to a small extent divergent at their free extremities. The bite, like that of all flies, is rather a stab than a bite, and is effected by a beak-like process of the head, the blood of the animal pricked in this way being drawn into the fly's mouth by a sucking action of the gullet. The tsetze flies appear to be especially greedy and are said to gorge themselves to such an extent that the blood taken in from one animal overflows the gullet, and so contaminates the wound inflicted by the fly on the next animal it visits. It is at the present moment assumed very generally that this is the way in which

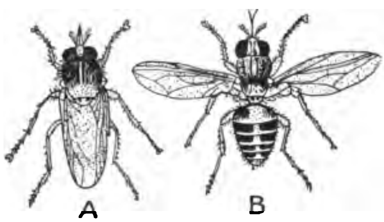


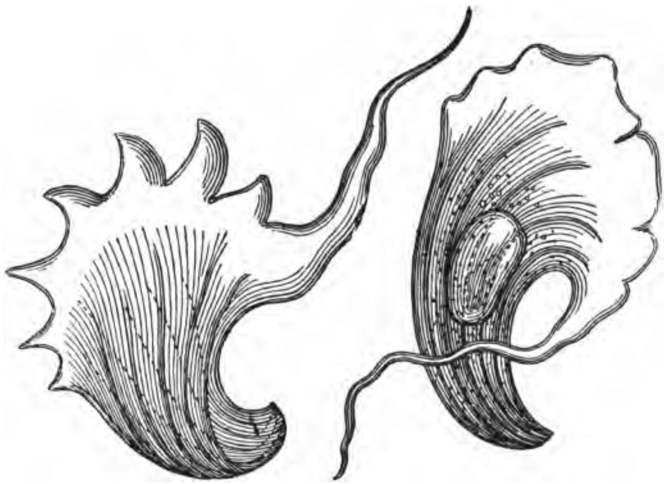
FIG. 48.

Tsetze flies—*Glossina morsitans*—magnified two diameters. This is the "fly" of the Nagana or horse and cattle disease of South Africa. The *Glossina palpalis*, which carries the *Trypanosoma Gambiense* causing sleeping sickness, is very closely similar to it in appearance.

infection is produced. But it is not at all improbable that the trypanosome undergoes some kind of multiplication and change of form when sucked into the tsetze fly as happens in the case of the malaria parasite when swallowed by the *Anopheles* gnat. No such change has yet been discovered in regard to the trypanosome of sleeping sickness; but it cannot be said that the matter has been exhaustively studied, or that a negative conclusion is justified.[1]

[1] Professor Minchin investigated this subject during 1905 in Uganda whither he went on behalf of the Tropical Diseases Committee of the Royal Society. He did not discover anything corresponding to the development of the malarial parasite in the gnat, but his investigations are not yet brought to a conclusion (December, 1906).

As to the parasite itself—the trypanosome—a long and very interesting story has now to be told. The first blood-parasite ever made known to naturalists and medical men was that to which Gruby, in 1843, gave the name *Trypanosoma sanguinis*. He found it in the blood of the common frog. We have here reproduced a figure



A B

FIG. 49.

The earliest discovered Trypanosome, described by Gruby in 1843 as "*Trypanosoma sanguinis*" and found by him in the blood of the common esculent Frog.

It was not noticed again until it was re-discovered by Lankester in 1871, who published the above figure of it in the *Quarterly Journal of Microscopical Science* in that year.

of this original trypanosome (fig. 49). Similar parasites had been seen, but not named, in the blood of fishes. These trypanosomes are all very minute and of a somewhat elongated form, a fair average length being one thousandth of an inch. They are simple protoplasmic animals, consisting of one single nucleated corpuscle.

The protoplasm is drawn out at one end of the creature into a motile undulating thread, and from the point where this joins the body a membranous undulating crest extends along the greater part of the animal's length. There is no mouth, nutrition being effected by the imbibition of soluble nutrient matter.

After a long interval Gruby's trypanosome was rediscovered in 1871; and then several kinds were described in the blood of tortoises, fishes and birds. In 1878, Dr. Timothy Lewis found a parasite in the blood of rats, at first in India, and subsequently in the common rats of London sewers. This parasite resembles a trypanosome in many respects (fig. 46A), but was very properly given a distinct name by Savile Kent, who called it "Herpetomonas." This name has, however, been dropped; and the rat's-blood parasite is spoken of as a trypanosome. It is the *Trypanosoma Lewisii*, and was the first of these trypanosomes to be found in the blood of a mammalian animal. The *Trypanosoma Lewisii* of the rat's blood seems to do no harm to the rat, in which it swarms, multiplying itself by longitudinal fission; nor is it at present known to produce any trouble in other animals when transferred to their blood. Similarly, the frog's trypanosome seems to exist innocently in the frog's blood.

The next trypanosome discovered (1880) was, however found in the blood of camels, horses, and cattle suffering from a deadly disease known in India by the name "surra." It is called *Trypanosoma Evansii*, after the observer who detected it. Trypanosomes now began to get a bad name, for the next was discovered in animals afflicted by a North African disease known to French veterinaries as "dourine." This trypanosome was called *T. equiperdum*.

A little later, namely, in the year 1895, came Bruce's discovery of a trypanosome associated with a tsetze fly in the production of the terrible nagana disease of the "fly-belts" of South Africa, which renders whole territories impassable for horses or cattle (fig. 46B). The remarkable and important observation was made by Bruce that this trypanosome (known as *T. Brucei*) inhabits the blood of big game without injuring them, just as the rat's trypanosome inhabits the rat's blood without producing disease; and that it is only when the trypanosome is carried from these natural wild "hosts" to domesticated animals introduced by man, such as horses asses, cattle, and dogs, that disease results. The wild animals are "immune" to Bruce's trypanosome; the introduced animals are poisoned by the products of its growth and fissile multiplication in their blood.

Since Bruce's researches on nagana, a trypanosome, *T. equinum* (fig. 46D), has been discovered in the horse-ranches of South America, where it causes deadly disease, the *mal de caderas*, among the collected horses; and a curiously large-sized trypanosome has been found by Theiler in the blood of cattle in the Transvaal. Down to a recent date no trypanosome had been found in the blood of man; and indeed it is almost certain that none of the kinds hitherto mentioned can survive in his blood. But in 1902 Dutton discovered a trypanosome in the blood of a West African patient; and a few other cases were noted. This trypanosome of human blood was called by Dutton *T. Gambiense*. It was not found to be connected with any serious symptoms, a little fever being the only disturbance noted. It now, however, appears that this trypanosome in the blood is the preliminary stage of the infection which ends in sleeping sickness; and, as we have seen, in a population

seriously attacked by sleeping sickness, as is that of Uganda, as many as 28 per cent. of the people have trypanosomes in their blood.

There is no ground at present known for distinguishing Dutton's *T. Gambiense* of human blood from that which Bruce has found to be so terribly abundant in Uganda, and to be the cause of sleeping sickness. Indeed all the trypanosomes of the blood of the larger mammalia are singularly alike in appearance; and the figure which is here given (fig. 50) of the trypanosome of sleeping sickness (*T. Gambiense*) might quite well serve to represent the *T. Evansii* of surra disease, the

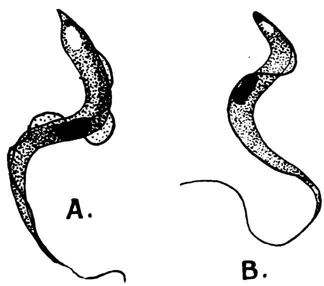


FIG. 50.

Trypanosome Gambiense, from the blood of men suffering from the early symptoms of sleeping sickness. A, after Bruce and Navarro; B, after Castellani. They show a large oval nucleus (drawn as a black mass), and a small black "micronucleus," or "blepharoplast" in front.

T. Brucei of nagana disease, or the *T. equinum* of the South American *mal de caderas*.

A most characteristic feature, which has been made out by the careful study of these trypanosomes by means of colouring reagents and very high powers of the microscope, is that, whilst there is a large granular nucleus there is also a small body at the anterior end of the animalcule which readily stains and is placed at the end of the root (so to speak) of the vibratile *flagellum* or free thread. This smaller nucleus has been variously called the "micronucleus," the "centrosome," and the "blepharoplast." It is identical with a structure

similarly placed in non-parasitic miscroscopic animals to which trypanosoma is undoubtedly related. We find it in the phosphorescent noctiluca of our seas, and in various animalcules called "Flagellata."

The creature drawn in our fig. 50 is, then, the typical trypanosome. It is this which the medical investigator looks for in his human or animal patients; it is this which he has regarded as the sign and proof of infection. Experiments have shown that, though so much alike in appearance in the different diseases we have named, yet each trypanosome has its own properties. Human blood-

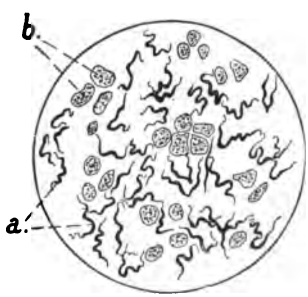


FIG. 51.

The Trypanosome (*T. equiperdum*) of the disease called "Dourine," as seen alive in the blood of a rat, eight days after inoculation.

A, the actively wriggling cork-screw-like parasites; B, the blood-corpuscles of the rat. This figure, of comparatively low magnification, gives an indication of the relative size of the parasites and the blood-corpuscles.

The blood-corpuscles are about $\frac{1}{5000}$th of an inch each in diameter.

serum is poisonous to one and not to another; an animal immune to one is not immune to another. At present no treatment has been discovered which will destroy the parasites when once they have effected a lodgment, or act as an antidote to the poison which they produce in the infected animal or man. But the fact that in some cases an animal may become immune to the attack of the parasite which usually is deadly to its kind, gives hope of an eventual curative treatment for trypanosome infection; as does also the fact that the serum of some animals acts as a poison to trypanosomes which flourish in other animals.

With regard to immunity, it must always be remembered that we are liable to confuse two different conditions under this one term. An animal may be said to be immune to a blood-parasite because that parasite is actually unable to live in its blood. On the other hand an animal is often said to be immune to a parasite when the parasite can and does flourish in its blood or tissues but produces no poisonous effect. A more precise nomenclature would describe the attacked organism in the first case as "repellent," for it repels the parasite altogether; in the second case as "tolerant," for it tolerates the presence and multiplication of the parasite without suffering by it.

We have yet to learn a good deal more as to the repulsion and the toleration of the trypanosome parasites by mammals and man. Still more have we to learn about the life-history of the trypanosome. At the moment of writing, absolutely nothing has been ascertained as to the life-history of the trypanosomes of mammalian blood, except that they multiply in the blood by longitudinal fission. Our ignorance about them is all the more serious since other trypanosomes, discovered by Danilewsky in birds, have been studied and have been shown to go through the most varied phases of multiplication and change of size and shape, including a process of sexual fertilisation like that of the malaria parasite, to which, indeed, it now seems certain the trypanosomes are very closely allied.

It is to Dr. Schaudinn,[1] that we owe a knowledge of some most extraordinary and important facts with regard to the trypanosomes parasitic in the blood of the little stone-owl of southern Europe (*Athene noctua*). These facts are so remarkable that, were Dr. Schaudinn not known

[1] Dr. Schaudinn died in 1906. He was only 35 years of age.

as a very competent investigator of microscopic organisms we should hesitate to accept them as true. Supposing, as is not improbable, that similar facts can be shown in regard to the trypanosomes of mammalian blood, the conclusions which our medical investigators have based upon a very limited knowledge of the form and life-history of the trypanosomes occurring in diseases such as sleeping sickness, surra, and nagana, are likely to be gravely modified, and practical issues of an unexpected kind will be involved.

As has already been pointed out in this article, the British Government has no staff of public servants trained to deal with the world-wide problems of sanitation and disease which necessarily come with increasing frequency before the puzzled administrators of our scattered Empire. There is no provision for the study of the nature and history of blood-parasites in this country, that is to say, no provision of laboratories with the very ablest and exceptionally-gifted investigators at their head[1]. We play with the provision of an adequate army, officers, and equipment to fight disease, which annually destroys hundreds of thousands of our people, much as barbarous states or bankrupt European kingdoms play with the provision of an ordinary army and navy. Their forces exist on paper, or even in fact, but have no ammunition, no officers, and no information; and there is no pay for the soldiers or sailors. Dr. Schaudinn, on the other hand, carried on his researches as an officer of the German Imperial Health Bureau of Berlin; and the account of them was published in the official Report of that important department of the German imperial administrative service three years ago.

[1] Since this was written a professorship of Protozoology has with the assistance of the Colonial Office been established in the University of London. This is a first step towards a recognition of the duty of the State in this matter.

It is not possible here to give a full report on Dr. Schaudinn's work; but it appears that he has studied two distinct species of trypanosoma, both occurring side by

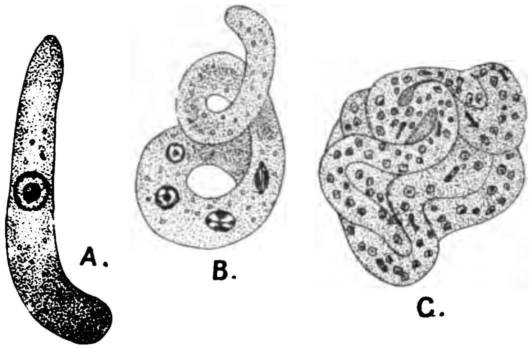


FIG. 52.

Trypanosoma Ziemanni, from the gut of the gnat (*Culex*), having been sucked in with the blood of the owl (*Athene noctua*). A, fertilized vermiform stage. B, multiplication of nucleus. C, elongation and coiling, with increase of nuclei (*after* Schaudinn).

side in the blood of the little stone-owl, and already seen but incompletely studied, by Danilewsky and Ziemann. The second of the two species of trypanosome is in some

FIG. 53.

Minute neutral Trypanosomes in the gut of the gnat liberated from the coiled form of Fig. 52, C (*after* Schaudinn).

respects the more remarkable. Schaudinn calls it *Trypanosoma Ziemanni*; and from the figures which are here given (figs. 4, 5, 6, and 7), copied from his article, with the explana-

tions below the figures, the reader will at once see what an extraordinary range of form and mode of multiplication is presented by this one species of trypanosome. Space will not permit us to comment on these various phases beyond noting how assuredly such forms would have escaped recognition as belonging to the trypanosome history if seen, before Dr. Schaudinn's memoir was printed, by any of our medical commissioners blindly exploring round about the diseases caused by trypanosomes in man and mammals.

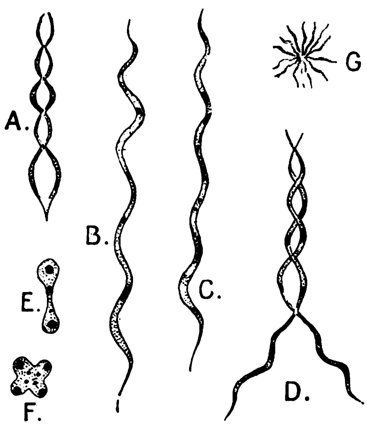


FIG. 54.

A, B, C, D, Elongated spiral forms of *Trypanosoma Ziemanni* (some intertwined) developed from those of Fig. 53—showing transverse division, nucleus, and blepharoplast.

E, F, pear-shaped forms resulting from the contraction of forms like A; G, a cluster of very minute individuals.

These forms are observed in the gnat and also in the blood of the owl, into which they pass when the gnat bites that bird, and there give rise to the large male and female Trypanosomes seen in Fig. 55 (*after* Schaudinn).

One very astonishing and revolutionary fact discovered by Schaudinn we must, however, especially point out. Medical men have long been acquainted with the spirillum, or spiral threads, discovered by Obermeyer in the blood of patients suffering from the relapsing fever of eastern Europe. These were universally and without question regarded as Bacteria (vegetable organisms) and referred to the genus "Spirochæta" of Ehrenberg. They were called *Spirochæta Obermeieri*; and relapsing fever was held to be a typical case of a bacterial infection of the blood.

It is now shown by Schaudinn that the blood-parasite spirochæta is a phase of a trypanosome (fig. 54); that it has a large nucleus and a micronucleus or blepharoplast, neither of which are present in the spiral Bacteria; and, further, that it alters its shape, contracting so as to present the form of minute oval or pear-shaped bodies, each provided with a larger and a smaller nucleus (fig. 54, E, F). These oval bodies are often engulfed by the colourless corpuscles

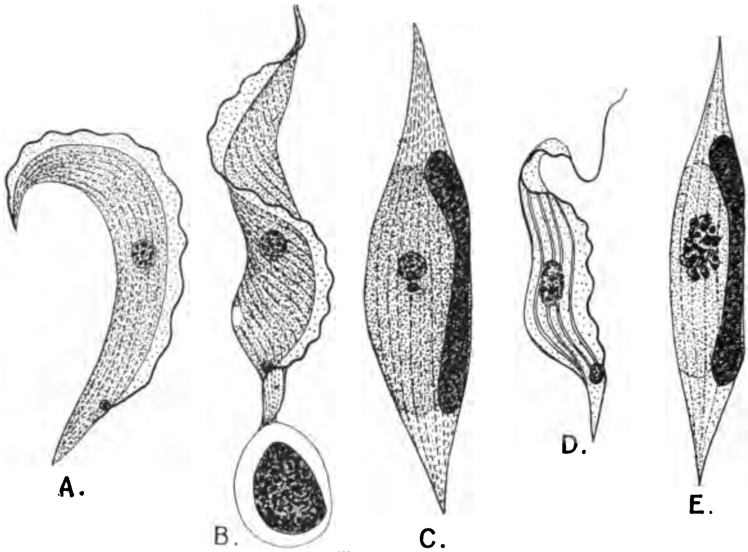


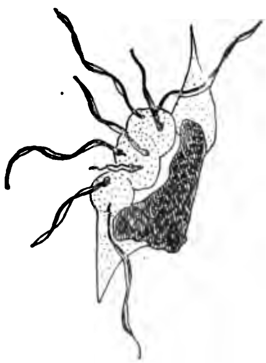
FIG. 55.

Trypanosoma Ziemanni, from the blood of the little owl. The stages shown in Figs. 52—54 are passed inside the gnat. The spiral and pear-shaped bodies of Fig. 54 pass from the gnat's proboscis into the blood of the little owl, and grow there into the large forms here figured. A, B, and C are females, destined to be fertilized by spermatozoa (see Fig. 21) when swallowed by a gnat. D and E are male Trypanosomes, which will give rise each to eight fertilizing individuals or spermatozoa as shown in Fig. 56—when swallowed by a gnat.

(phagocytes) of the blood; and it is in the highest degree probable that in this condition they have been observed in some tropical diseases without their relation to the spiral forms being suspected. The corpuscles lately described

by Leishman, in cases of a peculiar Indian fever, are very probably of this nature, as are also similar bodies recently described in Delhi sore. On the whole, it may safely be said that the researches of Dr. Schaudinn, of which only a preliminary account has yet been published, have widely modified our conceptions as to these blood-parasites, and must lead to important discoveries in regard to diseases caused by them in mammals and in man.

The facts that wild game serve as a tolerant reservoir of trypanosomes for the infection of domesticated animals



Male *Trypanosoma Ziemanni*, giving rise by nuclear division to eight spermatozoa or microgametes. From the stomach of the gnat (*Culex*).

Each of these penetrates and fuses with the substance of a female Trypanosome, swallowed at the same time or already taken in by the gnat. The fertilized animalculæ is the vermiform motile stage of Fig. 52, A; and so we return to the starting-point of the cycle (*after* Schaudinn).

FIG. 56.

by the intermediary of the tsetze fly, and that native children in malarial regions act the same part for the malarial parasite and mosquito, suggest very strongly that some tolerant reservoir of the sleeping-sickness trypanosome may exist in the shape of a hitherto unsuspected mammal, bird, or insect. The investigation of that hypothesis and the discovery of the reproductive and secondary forms of the mammalian trypanosomes are the matters which now most urgently call for the efforts of capable medical officers. But we must not be sanguine of rapid progress, since men of the scientific quality

needful for pursuing these enquiries are not numerous; and those who exist are not endowed with private fortunes, as a rule. At the same time no attempt is made by the British Government to take such men into its pay, or to provide for the training and selection of such officers.[1]

The relations of parasites to the organisms upon or in which they are parasitic, and the relation of man, once entered on the first steps of his career of civilisation, to the world of parasites, form one of the most instructive and fascinating chapters of natural history. It cannot be fully written yet, but already some of the conclusions to which the student is led in examining this subject have far-reaching importance and touch upon great general principles in an unexpected manner.

Before the arrival of man—the would-be controller, the disturber of Nature—the adjustment of living things to their surrounding conditions and to one another has a certain appearance of perfection. Natural selection and the survival of the fittest in the struggle for existence lead to the production of a degree of efficiency and harmonious interaction of the units of the living world, which, being based on the inexorable destruction of what is inadequate and inharmonious as soon as it appears, result in a smooth and orderly working of the great machine, and the continuance by heredity of efficiency and a high degree of individual perfection.

Parasites, whether microscopic or of larger size, are not, in such circumstances, the cause of widespread disease or suffering. The weakly members of a species may be destroyed by parasites, as others are destroyed by beasts of prey; but the general community of the species, thus weeded, is benefited by the operation. In

[1] See footnote on p. 179.

the natural world the inhabitants of areas bounded by sea, mountain, and river become adjusted to one another; and a balance is established. The only disturbing factors are exceptional seasons, unusual cold, wet, or drought. Such recurrent factors may from time to time increase the number of the weakly who are unable to cope with the invasions of minute destructive parasites, and so reduce, even to extermination the kinds of animals or plants especially susceptible to such influences. But anything like the epidemic diseases of parasitic origin with which civilised man is unhappily familiar seems to be due either to his own restless and ignorant activity or, in his absence, to great and probably somewhat sudden geological changes—changes of the connexions, and therefore communications, of great land areas.

It is abundantly evident that animals or plants which have, by long æons of selection and adaptation, become adjusted to the parasites and the climatic conditions and the general company (so to speak) of one continent may be totally unfit to cope with those of another; just as the Martian giants of Mr. H. G. Wells, though marvels of offensive and defensive development, were helpless in the presence of mundane putrefactive bacteria and were rapidly and surely destroyed by them. Accordingly, it is not improbable that such geological changes as the junction of the North and South American continents, of North and South Africa, and of various large islands and neighbouring continents, have, in ages before the advent of man, led to the development of disastrous epidemics. It is not a far-fetched hypothesis that the disappearance of the whole equine race from the American continent just before or coincidently with the advent of man—a region where horses of all kinds had existed in greater

variety than in any other part of the world—is due to the sudden introduction, by means of some geological change, of a deadly parasite which spread as an epidemic and extinguished the entire horse population.

Whatever may have happened in past geological epochs, by force of great earth-movements which rapidly brought the adaptations of one continent into contact with the parasites of another, it is quite certain that man, proud man, ever since he has learnt to build a ship, and even before that, when he made up his mind to march aimlessly across continents till he could go no further, has played havoc with himself and all sorts of his fellow-beings by mixing up the products of one area with those of another. Nowhere has man allowed himself—let alone other animals or even plants—to exist in fixed local conditions to which he or they have become adjusted. With ceaseless restlessness he has introduced men and beasts and plants from one land to another. He has constantly migrated with his herds and his horses, from continent to continent. Parasites, in themselves beneficent purifiers of the race, have been thus converted into terrible scourges and the agents of disease. Europeans are decimated by the locally innocuous parasites of Africa; the South Sea islanders are exterminated by the comparatively harmless measles of Europe.

A striking example of the disasters brought about by man's blind dealings with Nature—disasters which can and will hereafter be avoided by the aid of science—is to be found in the history of the insect phylloxera and the vine. In America the vine had become adjusted to the phylloxera larvae, so that when they nibbled its roots the American vine threw out new root-shoots and was none the worse for the little visitor. Man in his blundering way introduced the American vine, and with it the

phylloxera, to Europe; and in three years half the vines in France and Italy were destroyed by the phylloxera, because the European vines had not been bred in association with this little pest, and had not acquired the simple adjusting faculty of throwing out new shoots.

But it is not only by his reckless mixing up of incompatibles from all parts of the globe that the unscientific man has risked the conversion of paradise into a desert. In his greedy efforts to produce large quantities of animals and plants convenient for his purposes, and in his eagerness to mass and organise his own race for defence and conquest, man has accumulated unnatural swarms of one species in field and ranch and unnatural crowds of his own kind in towns and fortresses. Such undiluted masses of one organism serve as a ready field for the propagation of previously rare and unimportant parasites from individual to individual. Human epidemic diseases as well as those of cattle and crops, are largely due to this unguarded action of the unscientific man.

A good instance of this is seen in the history of the coffee plantations of Ceylon, where a previously rare and obscure parasitic fungus, leading an uneventful life in the tropical forests of that country, suddenly found itself provided with an unlimited field of growth and exuberance in the coffee plantations. The coffee plantations were destroyed by this parasite, which has now returned to its pristine obscurity. Disharmonious, blundering man was responsible for its brief triumph and celebrity. Dame Nature had not allowed the coffee fungus more than a very moderate scope. Man comes in and takes the reins; disaster follows; and there is no possibility of return to the old régime. Man must make his blunders and retrieve them by further interference—by the full use of his intelligence, by the continually increasing ingenuity of his control of the

physical world, which he has ventured to wrest from the old rule of natural selection and adaptation.

The adjustment of all living things to their proper environment is one of great delicacy and often of surprising limitation. In no living things is this more remarkable than in parasites. The relation of a parasite to the "host" or "hosts" in which it can flourish (often the host is only one special species or even variety of plant or animal) is illustrated by the more familiar restriction of certain plants to a particular soil. Thus the Cornish heath only grows on soil overlying the chemically peculiar serpentine rocks of Cornwall. The two common parasitic tape-worms of man pass their early life the one in the pig and the other in bovine animals. But that which requires the pig as its first host (*Tœnia solium*) cannot use a bovine animal as a substitute; nor can the other (*Tœnia mediocanellata*) exist in a pig. Yet the difference of porcine and bovine flesh and juices is not a very patent one; it is one of small variations in highly complex organic chemical substances. A big earth-worm-like stomach-worm flourishes in man, and another kind similar to it in the horse. But that frequenting man cannot exist in the horse, nor that of the horse in man. Simpler parasites, such as are the moulds, bacteria, and again the blood-parasites, trypanosoma, etc., exhibit absolute restrictions as to the hosts in which they can or can not flourish without showing specific changes in their vital processes. Being far simpler in structure than the parasitic worms, they have less "mechanism" at their disposal for bringing about adjustment to varied conditions of life. The microscopic parasites do not submit to alterations in the chemical character of their surroundings without themselves reacting and showing changed chemical activities. A change of soil (that is to say of

host) may destroy them; but, on the other hand, it may lead to increased vigour and the most unexpected reaction on their part in the production of virulent chemical poisons.

We are justified in believing that until man introduced his artificially selected and transported breeds of cattle and horses into Africa there was no nagana disease. The *Trypanosoma Brucei* lived in the blood of the big game in perfect harmony with its host. So, too, it is probable that the sleeping-sickness parasite flourished innocently in a state of adjustment due to tolerance on the part of the aboriginal men and animals of West Africa. It was not until the Arab slave raiders, European explorers, and india-rubber thieves stirred up the quiet populations of Central Africa, and mixed by their violence the susceptible with the tolerant races, that the sleeping-sickness parasite became a deadly scourge—a "disharmony" to use the suggestive term introduced by my friend Elias Metschnikow.

The adjustment of primaeval populations to their conditions has also been broken down by "disharmonies" of another kind, due to man's restless invention, as explained a few years ago in the interesting book of Mr. Archdall Reid on the "Present Evolution of Man." Not only does the human race within given areas become adjusted to a variety of local parasites, but it acquires a tolerance of dangerous drugs, such as alcohol and opium, extracted by man's ingenuity from materials upon which he operates. A race thus provided and thus immune imposes, by its restless migrations, on unaccustomed races the deadly poisons to the consumption of which it is itself habituated. The unaccustomed races are deteriorated or even exterminated by the poisons thus introduced.

Infectious disease, it was long ago pointed out, must be studied from three main points of view: (1) the life

history and nature of the disease-germ or infective matter; (2) the infected subject, his repellant or tolerant possibilities, and his predisposition or receptivity; (3) the intermediary or carrying agents. Whilst it is true that little or nothing has been done by the State in acquiring or making use of knowledge as to the first and second of these factors, with a view to controlling the spread of disease, it is the fact that much has been done both in the way of investigation and administration in relation to the third factor. The great public-health enquiries and consequent legislation in this country, in which scientific men of the highest qualifications, such as Simon, Farr, Chadwick, and Parkes, took part during the Victorian period, have had excellent results; to them are due the vast expenditure at the present day on pure water, sewage disposal, and sanitary inspection. But little or nothing has been done in regard to the first and second divisions of the subject, in which the less organised portions of the British Empire are more deeply concerned than in waterworks and sewer-pipes. It is still contested whether leprosy (which is a serious scourge in the British Empire, though expelled from our own islands) is a matter of predisposition caused by diet or solely due to contagion; and yet it is left to individual practitioners to work out the problem. The State prepares vaccine lymph in a cheap and unsatisfactory way for the use of its, till recently, compulsorily vaccinated citizens; but the State, though thus interfering in the matter of vaccine, has spent no money to study effectively and so to improve the system of vaccination. Here and there some temporary and ineffective enquiry has been subsidised by a Government office; but there is no great army of investigators working in the best possible laboratories, led by the ablest minds of the day, with the constant object

of improving and developing in new directions the system of inoculation. Surely if compulsion, or every pressure short of compulsion, is justified in enforcing vaccine inoculation on every British family, it would be only reasonable and consistent to expend a million or so a year in the perfection and intelligent control of this remedy by the most skilled investigators. Yet not a halfpenny is spent by the British Government in this way. Medicine is organised in this country by its practitioners as a fee-paid profession; but as a necessary and invaluable branch of the public service it is neglected, misunderstood, and rendered to a large extent futile by inadequate funds and consequent lack of capable leaders. The defiant desperate battle which civilised man wages with Nature must go on; but man's suffering and loss in the struggle—the delay in his ultimate triumph—depend solely on how much or how little the great civilised communities of the world seek for increased knowledge of nature as the basis of their practical administration and government.

POSTSCRIPT, December, 1906.—Messrs. Thomas and Breinl, of the Liverpool School of Tropical Medicine, two years ago discovered and published the fact that an arsenical aniline product known as "atoxyl" when injected into patients suffering from Sleeping Sickness destroys the parasite and promises to be a cure for this terrible infection. Experiments are in progress in many quarters in regard to this treatment, but certainty can only be arrived at by prolonged observation of the patients. The newspapers have lately, in error, attributed this discovery to Dr. Robert Koch of Berlin, who has merely confirmed the observations of the earlier workers.—E. R. L.

DATE DUE

JUN 27 1984			
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MAY 26 1984			
JAN 23 1994			